DUDE, WHERE'S MY ROBOT CAR?

How to take the brakes off the driverless revolution

NewScientist

WEEKLY February 14 - 20, 2015

THE AGE OF PLENTY

We've built a civilization on the rarest of metals. How much longer can it last?

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The battle to prevent a second deadly epidemic

COSMIC FOG
The dark ages just got 150 million years longer

TUNNEL VISION
Are underground farms the future of lettuce?

INSIDE-OUT ORIGINS
The biological convulsion that created complex life

Fuel consumption figures mpg (litres/100km) and CO_2 emissions (g/km), Audi A3 Sportback e-tron: Urban: N/A, Extra Urban: N/A, Combined/ test results: one when the battery is fully charged and the other when the battery is discharged. The two test results are a weighted average, petrol engine generating electricity. Standard EU Laboratory Test figures are for comparative purposes between vehicles and may not reflect

Audi
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What Car? Electric Car of the Year 2015.

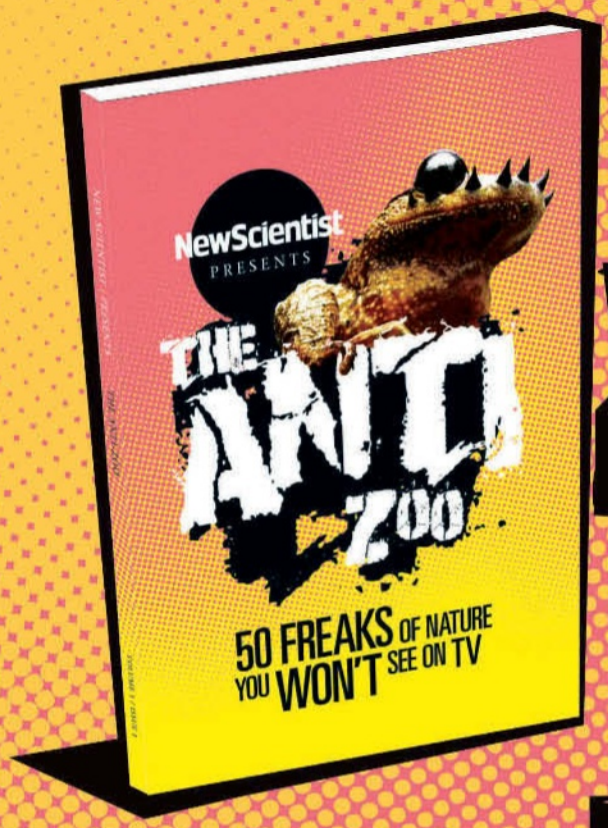
The A3 Sportback e-tron is the first of our plug-in hybrid cars. Unlike other hybrids where a lot of effort has been made to make the car look different, e-tron has been designed to make a difference. On the one hand, it can deliver up to 176.6mpg and only emit 37g/km of CO_2. On the other, it will deliver all the performance you'd expect from an Audi. In fact, What Car? have already named it Electric Car of the Year 2015, so the judges seem to agree that the A3 Sportback e-tron is indeed like a car, but better.

The new Audi A3 Sportback e-tron.

etter_

WHAT CAR?
Car of the Year 2015
Best electric car

weighted: 176.6 mpg (1.6 litre/100km). CO_2 emissions: 37g/km. The 'Combined/weighted' fuel consumption CO_2 figures calculated from two taking into account mileage range on battery power only, providing a figure in a variety of charge conditions. Extended range achieved by 1.4 TFSI real driving results. Images for illustration purposes.



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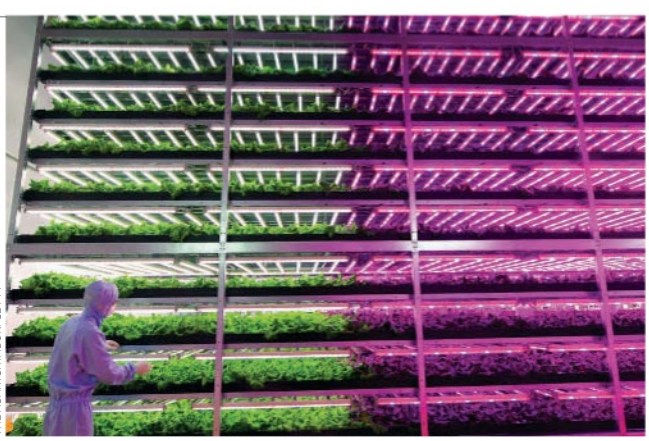

THE ASAHI SHIMBUN/GETTY

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It's not just the brain's grey matter that matters

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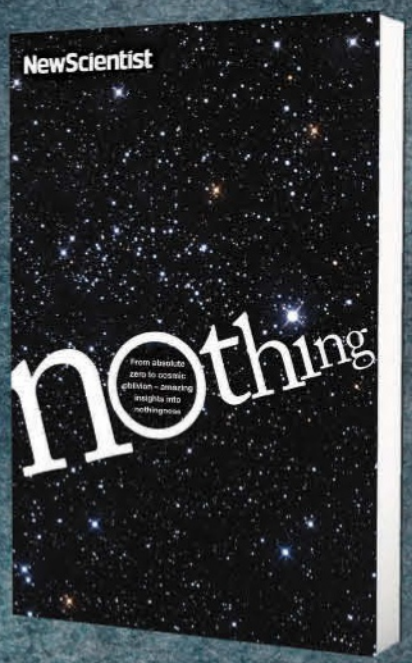
Everything you always wanted to know about nothing



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SVEN TORFINN/PANOS

More stuff, less guilt

It's ethics rather than minerals that are in short supply

IF YOU'VE ever felt a pang of guilt when you open a drawer and see an old mobile phone, jilted at the first opportunity for a slimmer, sexier model, you could take comfort from the fact you're not alone. Hundreds of millions of phones are dumped every year; estimates suggest that the majority end up gathering dust in their owners' houses.

Guilt is probably an appropriate response, though exactly what to feel guilty about is not easy to pin down. Is it because we caved in to consumerist urges and ditched a perfectly good phone? Is it because somebody less fortunate could be using that phone? Is it because the materials in it are becoming scarce and need to be recycled, if only we could get around to doing it?

For the average consumer, there are no easy answers. The vast infrastructure that creates and destroys our gadgets is as opaque as their inner workings. In the face of this knowledge gap, shoving a phone in a drawer and forgetting about it is an understandable response.

So should we feel guilty, and what about? One concern is off the table. Many voices predicted that the exotic elements at the heart of some essential components in phones and tablets would become so scarce as to bring the digital revolution grinding to a halt. That idea has been shown to be false: a combination of human ingenuity, abundant resources and market forces means these elements are practically inexhaustible (see page 35).

Nonetheless, raw materials are not guilt-free. Your phone may well contain "conflict minerals", mined by forced labourers under the yoke of militia groups in war-torn countries.

"Many discarded gadgets end up being trafficked out of Western countries to avoid clean-up costs"

The processing of ores can also have devastating environmental and human impacts. Much of the industry is situated in places where environmental and labour regulations are lax, non-existent or not enforced.

There is scandal at the other end of the life cycle too. Recycling rates are poor: in the UK, 75 per cent of electronic waste ends up in landfill. Many discarded gadgets end up being trafficked out of the West to avoid clean-up costs. Interpol estimates that one in three shipping containers leaving Europe is packed with e-waste destined for illegal dumping in the developing world. This results in major health hazards to people doing the dirty work of recycling (see page 24). It also means that millions of tonnes of potentially useful metals are lost, forcing us to extract more ore, burn more fossil fuels, exploit even more workers and cause even more environmental degradation.

These are solvable problems. Interpol has set up an arm to deal with traffickers, and the UN has taken on a role in fighting the problem of waste generation. US law now forces corporations that buy minerals to operate a transparent supply chain, helping to ensure they are not buying conflict minerals.

Industry has shown that not all processing has to take place in the developing world. A company called Less Common Metals, for example, processes ore in the UK, adhering to EU environmental laws while making a tidy profit.

There is much more to do. We are unlikely to damp down demand for ever shinier, smarter gadgets. So the companies that are so good at giving us what we want should apply their ingenuity to taking away what we don't want – including the guilt. We engineered our way out of a mineral crisis. We can surely do something about drawers full of old phones. ■

LUCY NICHOLSON / REUTERS

Don't be scared to vaccinate

Myths make measles soar

MEASLES is exploding because parents are afraid to have their children vaccinated. That's the message emerging from the US and Germany this week. Anti-vaccination scaremongering is believed to be driving the outbreaks.

By Monday, 486 cases had been reported so far this year to the Robert Koch Institute in Berlin, which monitors the spread of infectious disease in Germany – up from 446 cases for the whole of 2014. In the US, the Centers for Disease Control in Atlanta, Georgia, had reported 121 cases in the same time frame.

In both countries, health professionals are blaming parents who reject the triple MMR vaccine for their children, which protects against measles, mumps and rubella.

According to Mobeen Rathore, a member of the American Academy of Pediatrics' committee on infectious diseases, the upsurge is a sign that myths about vaccines need to be dispelled globally, including any link with autism. "We need to increase rates by educating people and having stronger laws that require childhood immunisations, and removing loopholes allowing parents to seek exemptions," says Rathore.

In Germany, 344 of the cases have been in Berlin. "The main causes are low immunisation rates in toddlers, adolescents and younger adults, which results in missing 'herd immunity' for children too young to be vaccinated," says Dorothea Matysiak-Klose of the Robert Koch Institute.

Shields up

IT'S a busy week for audacious spacecraft. As we went to press, two missions were scheduled to launch into space and return using innovative re-entry techniques.

"Rocket re-entry will be much tougher this time around due to it being a deep space mission"

On Tuesday, SpaceX was expected to launch the DSCOVR satellite, which will monitor the effect space weather has on Earth. It is the firm's first launch to deep space, rather than just Earth orbit, and its second attempt to land the first stage of its Falcon 9 rocket on a barge.

Last month, SpaceX's earlier try at landing ended in a spectacular crash and this time is likely to be even more difficult, said CEO Elon Musk before the launch. "Rocket re-entry will be much tougher this time around due to deep space mission. Almost 2 times the force and 4 times the heat," he tweeted.

The next day, the European Space Agency was due to launch its Intermediate eXperimental Vehicle (IXV), a small spaceplane designed to test re-entry technology that could eventually help deep space missions.

Most re-entry vehicles are heat-resistant capsules that can't control their descent, like those used in NASA's Apollo missions. The space shuttle, which landed like a plane, was an exception. ESA's IXV is a hybrid, shaped like the nose of the shuttle but with rear flaps instead of wings. If all goes to plan, the uncrewed craft will have safely splashed down.

Fatigue checklist

WHAT'S in a name? Chronic Fatigue Syndrome, a condition that debilitates as many as 2.5 million people in the US with exhaustion, should be renamed Systemic Exertion Intolerance Disease, according to the US Institute of Medicine (IOM).

As well as the name-change, the IOM has this week proposed a five-point checklist for diagnosis. Because the cause of the condition, also known as myalgic encephalomyelitis or ME, remains unknown, identifying the condition can be difficult.

"Our goal was to facilitate diagnosis," says Ellen Wright Clayton of Vanderbilt University in Nashville, Tennessee, and chair of the panel that drafted the report. "We hope these evidence-based diagnostic criteria provide a new foundation for future research regarding cause and treatment."

Simon Wessely at King's College London welcomes the criteria, but is less convinced by the name-change. "I'm concerned it may add to, not reduce, confusion around this condition," he says.

CAROL ARMSTRONG/ALSJ

Fly me to the moon and back

Moon mementos

WE'VE all got sentimental knick-knacks from our holidays bundled away in forgotten cupboards, but this is something else. Last week the US National Air and Space Museum revealed it had been given a bag of souvenirs brought back from the moon by astronaut Neil Armstrong. It has now placed some of the items on display.

The lunar keepsakes, which include the 16mm film camera used to document Armstrong's

"one small step" in 1969, were uncovered by Carol Armstrong, his widow. She found the bag while cleaning out a closet after his death in 2012. She handed them over to the museum in June 2013, which kept them secret while documenting the items.

Armstrong also kept a variety of cables, plus a tether he had used to support his feet while resting on the moon. "As far as we know, Neil has never discussed the existence of these items and no one else has seen them in the 45 years since he returned from the moon," said curator Allan Needell in a blog post about the find.

Fat chance of advice

GOVERNMENT advice may be a fat lot of good. A controversial study claims dietary guidelines issued on fat intake to reduce the risk of heart disease were not supported by evidence from clinical trials.

In 1977, the US government said that fat should make up no more than 30 per cent of an individual's diet, and saturated fats should be limited to 10 per cent of total energy intake. The same guidelines were issued in the UK in 1983.

Zoë Harcombe at the University of the West of Scotland, UK, and her colleagues studied the only seven relevant trials they could find from before 1983. They found no evidence to support the advice (*Open Heart*, doi.org/z2w).

However, the study has been criticised for looking solely at the trials. The guidelines may still have been based on good scientific evidence, says Christine Williams at the University of Reading, UK. They are usually developed using a range of evidence, not just trials.

"Dietary guidelines are usually developed using a range of evidence, not just clinical trials"

Plan B is a no-go

SOME plan. Curbing global warming by shading Earth from the sun could be quick and cheap but also irrational and irresponsible, says a geoengineering study from the US National Academies.

Making Earth more reflective to the sun's rays by sending mirrors into space or putting sulphur dioxide in the stratosphere – called albedo modification – could have "unanticipated, unmanageable and regrettable consequences" on the global climate, it says. Other impacts of carbon emissions, such as ocean acidification, would continue and if the techniques were ever stopped, rapidly soaring temperatures could have cataclysmic consequences.

The report marks a departure from previous reviews, such as the UK Royal Society's 2009 study, says Simon Nicholson at the American University in Washington DC. "The idea advanced by the Royal Society that albedo modification is some kind of Plan B has largely fallen out of favour," he says.

The report underlines that the best way to combat climate change is the simplest: curbing CO_2 emissions, although we may also need to enhance CO_2 removal from the atmosphere.

Deadly shark attacks on the rise

THE beach is off-limits. A surfer has died this week in the latest of a series of fatal shark attacks off the coast of Australia. But as police boats scour the ocean for the culprit, which attacked about 10 metres from the shore, there is no evidence that shark numbers have risen at all.

Tadashi Nakahara died after both his legs were severed at Shelly Beach in northern New South Wales. The incident occurred just a week after beaches further south were closed for a record nine days following shark sightings.

This is the third fatal attack in New South Wales in the past 12 months, and the sixth in Australia, compared with just four in 2012 and 2013 . But "there is no data to suggest that there has been an increase in shark numbers", says Christopher Neff from the University of Sydney. The rise in attacks could be random, or it could be driven by other factors that bring sharks closer to coast, such as small changes in thermal currents or bait fish movements. There may also be more people in the ocean, he says.

The attack at Shelly beach is thought to have been carried out by a great white shark and police are examining live-streaming footage of the beach that captured the incident.

However, Neff says it is ridiculous to search for the shark responsible, as a great white can travel between 70 and 125 kilometres a day. "You should just close the beach and it will naturally move on," he says.

CHRIS HYDE/GETTY

Not safe to surf

60 SECONDS

Recount those finches

We may need to rethink Darwin's finches. Differences in beak shape led biologists to classify them into some 15 species, but the first full genome analysis suggests some of the birds evolved the same beak shape independently. In fact, there may be 18 species in total (*Nature*, DOI: 10.1038/nature14181).

Bugs tackle diabetes

Need more insulin? Follow your gut. A team has engineered a bacterium present in some probiotic yoghurts to make the human hormone glucagon-like peptide-1. When fed to rats, the chemical triggered some gut cells to behave like pancreatic cells, producing insulin and lowering blood sugar (*Diabetes*, doi.org/z2s).

Break out the Havanas

Hola! Video streaming service Netflix is now available in Cuba, following the US government's lifting of trade restrictions. But it's not clear how many people will subscribe at $7.99 a month, given that most Cubans don't have ways to make international payments – or internet connections.

No STI-vaccine link

That should settle it. Some claim that vaccinating against the human papillomavirus, which can cause cancers and genital warts, encourages riskier sexual activity. But according to data covering 2005 to 2010, girls in the US who are vaccinated do not get more sexually transmitted infections than those who are not. Vaccination is thus unlikely to promote unsafe sex, the study concludes (*JAMA Internal Medicine*, doi.org/z2t).

Earth's two-bit heart

A virtual journey to the centre of the Earth shows that the innermost core has two distinct parts: the structure of their iron crystals distinguishes the two, seismic echoes reveal (*Nature Geoscience*, doi.org/z2r).

Don't give me that crap

Thought about having faeces transplanted into your gut? It can work wonders… but weird things can happen too, finds **Jessica Hamzelou**

AS MEDICAL procedures go, they're certainly not something to discuss over dinner. Faecal transplants are soaring in popularity as a treatment for a range of diseases. But a transplant from an overweight donor seems to have caused obesity in one recipient, raising the possibility that the process could also pass on other, more dangerous conditions.

Our gut bacteria appear to play a vital role in our health, and certain strains have been linked to disorders from asthma and eczema to diabetes, cancer and Parkinson's disease. Faecal transplants supposedly offer a way to repopulate the intestines of an unwell person with gut bacteria from a healthy person. At least 80 clinics in the US now offer the treatment, and one of the UK's leading centres, the Taymount Clinic in Hitchin, is relocating to larger premises to meet demand.

The treatments are a lifeline for people with recurrent *Clostridium difficile* infections of the gut, which cause diarrhoea and fever, and can be fatal. These infections can recur after antibiotic treatment, but are cured 90 per cent of the time after a faecal transplant.

"My colleagues will perform a faecal transplant and then notice that the person isn't depressed any more"

Colleen Kelly, a gastroenterologist at the Miriam Hospital in Providence, Rhode Island, has carried out around 200 faecal transplants for people with *C. difficile* infections. In 2010, she gave a transplant to a 32-year-old woman whose teenage daughter was the donor. The girl was borderline obese, says Kelly, but otherwise healthy. The transplant was a success and cleared up the woman's *C. difficile* infection.

Around a year later the woman returned, complaining of massive weight gain. She had always been a normal weight, but had become obese despite diet and exercise regimes – even a medically supervised liquid protein diet. "She said she felt like there was a switch inside her body," says Kelly. "No matter how much she ate or exercised, she couldn't take the weight off. She's still overweight now, and she's very frustrated."

It is the first recorded case of obesity apparently resulting from a faecal transplant (*Open Forum Infectious Diseases*, doi.org/zzr). Since it's a one-off, Kelly says she can't be sure of cause and effect. The antibiotics the woman also took could instead be to blame, says Martin Blaser, a microbiologist at New York University, who has found that these drugs can trigger obesity by wiping out "good bacteria".

The treatment seems effective against stubborn *C. difficile*

But researchers have already seen similar results in mice: lean mice may gain weight after receiving gut bacteria from obese ones. Separately, a team in the Netherlands tried giving faecal transplants from lean donors to obese people with metabolic syndrome – in which insulin is less able to lower their blood sugar levels – to see if they would lose weight. The recipients remained obese, but became more sensitive to insulin and better able to deal with sugar in their diet.

There is a possibility that other diseases linked to gut bacteria, such as immune disorders and cancer, could be transferred, says Kelly. "We don't know enough about the long-term risks."

"People have been wondering if something bad was going to happen," says Trevor Lawley at the Wellcome Trust Sanger Institute in Hinxton, UK. "It could potentially result in something more dangerous than obesity."

Spin-offs

Emma Allen-Vercoe, a microbiologist at the University of Guelph in Canada, says she wasn't surprised by the reported case of obesity. She knows of other doctors who have observed unexpected spin-offs after faecal transplants, but haven't reported individual cases in the past. "My colleagues have certainly seen some interesting things along the way," she says. "They will perform a faecal transplant for *C. difficile* and then notice that, hey, the person's ulcerative colitis has cleared up, or, hey, they are not depressed any more."

WHO'S THE PERFECT DONOR?

Think before you flush: your faeces could be earning you money. The Massachusetts-based company OpenBiome, which banks and sells frozen faecal samples, is offering up to $13,000 a year for contributions from healthy, clean-living individuals. But you'd have to pass a stringent screening test first.

Potential donors are asked to complete a questionnaire about disease risk. "Our donors tend to be highly educated students or young professionals with an average age of 26," says Zain Kassam, OpenBiome's chief medical officer. "They tend to be athletic and health-conscious… and I encourage a healthy, well-balanced diet with a lot of fibre."

Emma Allen-Vercoe at the University of Guelph in Canada went further to find the ideal donor, whose faeces could be used for a synthetic version of a faecal transplant. Her group wanted someone who had not taken antibiotics, didn't drink or smoke, and was healthy and in shape. They ended up using samples from a woman brought up in rural India.

Colleen Kelly, at the Miriam Hospital in Providence, Rhode Island, no longer uses overweight donors after one of her patients developed obesity (see main story).

A study in mice suggests that a faecal transplant can even pass on personality traits, so recipients may also want to consider the disposition of their donors. "I would pick the thinnest, nicest person who eats well," says Kelly.

Soon we can expect celebrities to start selling their own faecal samples for transplants, says Allen-Vercoe. "It sounds ridiculous, but I bet you someone will do it."

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CLAUDINE DOURYAGENCE VU/CAMERA PRESS LEFT: JENNIFER HULSEY/CDC/SPL

Weight gain – a trifling worry?

Kelly has her own stories. "I had one patient who had alopecia, and he had no hair on his body since he was 6 years old," she says. "After his faecal transplant, he actually started to grow hair again, and he managed to shave."

There are 68 registered clinical trials under way in the US, investigating transplants' potential for treating diabetes, Crohn's and HIV infection. But at the moment, there are no reliable records of how many people have had faecal transplants, and how many have experienced side effects. To move from anecdotal reports to firm evidence, Kelly is planning to launch a US national registry of faecal transplant procedures, tracking people for five years following treatment.

Kelly has now changed the way she screens people who offer to donate their faeces. "I have become very strict with my donors," she says, not using anyone who might even theoretically pose a disease risk. That includes people with "Parkinson's or multiple sclerosis or chronic fatigue syndrome, or anything that we just aren't sure about". She also discusses the risks at length with potential recipients.

It is unlikely that everyone receiving a faecal transplant gets to hear the same warnings, however, because a standardised clinical protocol has yet to be developed. Regulations vary around the world. In the UK, for example, faecal transplants are not regulated. The US Food and Drug Administration has approved their use, but only for *C. difficile* infections.

"It sounds ridiculous, but we can expect celebrities to start selling their own faecal samples"

At the same time, the number of people thought to be conducting their own faecal transplants at home is rising. Kelly advises against this, but Lawley points out that the area is impossible to regulate. "Faeces is not a drug or an organ – it's shit," he says. "You can't control what someone does in their bathroom."

Lawley hopes that the new case study will give people pause for thought. With recurrent *C. difficile*, the benefits are likely to outweigh any risks. But for other conditions, the picture is much hazier.

"Ultimately we'll have to develop a well-defined group of bugs," says Lawley, who is part of a team trying to identify the beneficial bacteria in faecal transplants. Other teams and companies are tackling the same problem. Allen-Vercoe is working with colleagues on a synthetic version of the faecal transplant – a tablet that contains carefully screened bacteria isolated from a healthy donor's stools.

Until then, however, people considering faecal transplants for conditions other than *C. difficile* may want to reconsider their options. "People need to be aware of the risks," says Allen-Vercoe. ■

Should the UK frack for gas?

Catherine Brahic asks if shale gas is the answer to our energy conundrum

THE UK, we are told, is gasping for gas, which accounts for nearly half of its energy use. Home-grown gas is drying up, leaving the country ever more reliant on imports. The solution, some say, is right beneath our feet: we just need to frack for shale gas.

The remarkable success of the dash for shale gas in the US has persuaded its proponents in the UK. The UK government backs it. The Environment Agency has just granted energy firm Cuadrilla permits for exploratory fracking at two sites in Lancashire. And an attempt by a group of MPs to impose a moratorium on fracking was defeated last month.

Meanwhile, NGOs say that fracking on UK soil would be an environmental disaster, one we should avoid at all costs. They cite a range of concerns, such as water and air pollution (see diagram, right). So would fracking really wreak havoc on the environment? And if not, should the UK press ahead and make use of this controversial source of gas?

The UK does need to re-think its energy supplies. The North Sea gas fields are reaching the end of their lives, most of its nuclear plants are to close by 2023, and a third of its coal-fired power stations are set to close by 2016 to meet European air quality regulations.

The greenest solution is a switch to renewables and the government has committed to getting 15 per cent of the nation's energy from these by 2020, and has promised to cut its greenhouse gas emissions to 80 per cent below 1990 levels by 2050.

But there is a catch. The sun doesn't shine and the wind doesn't blow 24/7. We do, however, consume energy around the clock.

"If gas replaces coal, that's great. But if it starts to push out renewables, it's no good"

Until we can develop the large batteries needed to even out energy supplied from renewables we need a more reliable source.

This is where fracking comes in. Geological surveys reveal that parts of the British Isles are made of methane-rich shale, where the sediment traps natural gas inside tiny bubbles. To extract this gas, companies drill down and then horizontally over large distances. They then pump water, sand and chemicals in, which fracture the shale, allowing the gas to escape and collect in the well.

Over the last decade in the US, fracking has caused both an energy revolution and furore

JIM WILSON/THE NEW YORK TIMES/REDUX/EYEVINE

Dash for gas

among environmental groups, mostly concerned about an increase in water pollution.

Avner Vengosh, a geochemist at Duke University in Durham, North Carolina, has been at the forefront of studies on the environmental effects of fracking. Just last month, he revealed that hazardous levels of ammonium, bromide and iodide were ending up in rivers as a result of fracking on New England's Marcellus shale (*Environmental Science & Technology*, doi.org/z2f). These come from deep inside the shale and are carried up to the surface along with the wastewater.

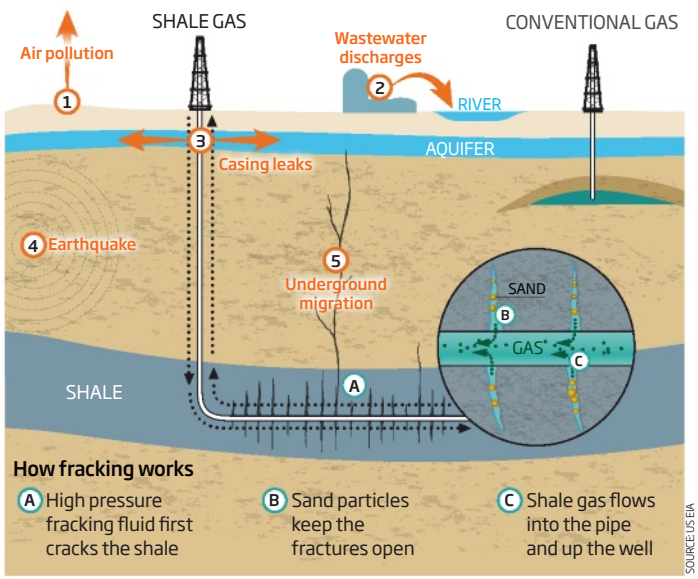
Minimising risk

But while news headlines pointed the finger only at fracking when such pollution occurred, Vengosh says his team found the same levels of pollution associated with conventional oil and gas operations. The problem, he says, is that oil and gas companies in the US are exempt from some federal regulation. In particular, in 2005 Congress exempted fracking chemicals from the Clean Water Act. Many conventional oil and gas operations now inject the same chemicals as for fracking into their wells. "The difference with shale is that it's closer to people's homes, so they see the impact," says Vengosh.

Vengosh is now working with the California water board to draw up stringent industry standards to address some of the federal regulatory failings. He says there are basic steps the UK could take to minimise the environmental risks. For instance, casings around drill wells should be thick, impermeable and routinely monitored for cracks to avoid any gas or chemicals contaminating drinking water. There should also be a 1 kilometre exclusion zone around drinking resources where fracking cannot occur. And live monitoring systems need to be put in place, so leaks are picked up in real time.

Risky business

There are a number of concerns about the environmental impact of fracking



1. AIR POLLUTION
The health effects of air pollution from fracking are poorly understood. Any methane leaks would compound global warming

2. WASTEWATER
In the US, toxic chemicals from wastewater have been found in rivers. European regulations should prevent this

3. CASING LEAKS
Chemicals can seep out of the fracking pipes into aquifers, but only if casings aren't thick enough or sufficiently monitored

4. EARTHQUAKES
Fracking may trigger earthquakes, although typically too small to be felt

5. UNDERGROUND MIGRATION
Fracking could link natural fractures in the rock, opening conduits for chemicals and gas. This can be avoided with prior geological surveys

The risks cannot be eliminated, but they can be minimised. "It's all manageable," he says. "It's just a matter of investment." Though, as with any fuel operation, there will always be a risk of accidents.

"We're in a much better position in Europe," says Ulrich Ofterdinger, a geologist at Queen's University Belfast, UK. "Like it or not we have a lot of regulation from Brussels that should force countries to put in place decent environmental frameworks."

Ofterdinger's concern is that politicians will press ahead with fracking licences and miss the opportunity to gather baseline geological data. The difficulty in the US, he says, is that by the time people became concerned about gas and chemicals seeping into their drinking water it was too late to find out if the contamination was due to natural processes.

Surveys will also help avoid areas where fracking could interlink natural cracks in the rock, allowing gas and chemicals to seep upwards from the horizontal drilling wells into aquifers.

The real clincher against fracking in the UK isn't in the chemicals, though – it's in time and emissions. Oil and gas industry representatives contacted by *New Scientist* estimate that it will take at least 10 years for the UK to produce a meaningful amount of shale gas, making it a poor substitute for dwindling North Sea production in the short term.

It also triggers concerns that once a fracking industry is in place, it will displace future renewables. "If gas replaces coal, that's great," says economist

"It will take 10 years to get enough shale gas from fracking to compensate for dwindling North Sea gas"

Paul Stevens of Chatham House in London. "But if it starts to push out renewables, it's no good."

And then there are emissions. There is no room for fracking if we want to make sure we don't go over 2 °C warming – the internationally agreed threshold for "dangerous" climate change. This is according to Kevin Anderson and John Broderick at the University of Manchester, who in as-yet-unpublished work crunched the numbers on emissions from UK shale gas.

That leaves the question of where the UK should turn for energy during the next decade or so. If fracking isn't the right fuel to bridge the gap to renewables then what is? Coal is more polluting than gas, and nuclear is at least as controversial as fracking.

The easiest option is to import more gas. But a lot of this gas originates in Russia, whose pipelines are leaky and the warming effect of methane on the atmosphere is 21 times greater than that of carbon dioxide.

"We need a Marshall plan for developing low carbon options," says Anderson. He is a strong proponent of increasing energy efficiency and cutting consumption. "For the average UK citizen, changes can be incremental."

His group is drawing up lists of ways in which the nation can cut back on its fossil fuel addiction, and calculating the impact of those changes on national emissions. Early results, he says, are promising. ■

ARTPARTNER-IMAGES/GETTY

Blind data

A dash of quantum to secure the cloud

Jacob Aron

THESE days it's easy to access ultra-powerful computers: just borrow one from Amazon, Microsoft or other firms offering cloud computing services. But analysing data with someone else's hardware makes it hard to keep it secret. Now it seems a dash of quantumness might be the best way to stay safe in the cloud.

In 2012, Stefanie Barz and her colleagues demonstrated ways of manipulating quantum states that can keep a server blind as it processes data. These kept cloud computing secure, but required a lot of back-and-forth traffic to eventually return the answer. So Barz, now at the University of Oxford, wondered if just a small amount of quantumness could provide a middle ground.

In a new experiment, Barz and her colleagues replicated a sort of cloud computation on a much smaller scale, using only a single bit. In one lab they set up a server "computer", which takes the role of a cloud provider like Amazon. The server can produce photons in a quantum state called a cobit.

Usually, quantum computing is done with qubits, which can be a 0, a 1 or a mix of both in various ways – thanks to quantum superposition. Cobits are a less quantum version that can only be 0, 1 or an exact superposition of both, giving them fewer possible states than qubits.

The server sends this cobit to the client "computer" – the user who wants to do some secret cloud computing – in another lab 50 metres away. The client is only capable of a very basic form of computation called an XOR logic gate.

"Quantum computing is usually done with qubits, but cobits are a less quantum version"

The client can't make its own cobits, but it can alter the state of the cobit it receives from the server in order to represent an encrypted form of the data it wants to crunch. The server can then perform a quantum measurement on the cobit to run a more powerful computation, called a NAND gate. In theory, using a NAND gate repeatedly could perform any computation, making this a neat demonstration of the scheme's potential.

The client's encryption means the server can't interpret the results of the calculations. The results only make sense once they have been passed back to the client, which can decrypt them.

The process is complex, but the upshot is that the client can do more powerful computation with the help of an external server, without the server learning anything about the computation – exactly what is needed for secure cloud computing. "The cobit enables the client to compute problems beyond her own power," writes the team (arxiv.org/abs/1501.06730).

"The concept is definitely interesting and addresses a very relevant problem," says Grégoire Ribordy, CEO of ID Quantique, a Swiss firm that sells quantum communications technology. But it might be difficult to scale up. "It is hard to say if this will really be practical one day." ■

Dark force keeps galactic dwarfs away

DARK energy is thought to be ripping apart the fabric of space-time on cosmological scales. But it now seems it may also have an influence on the scale of a single galaxy. If so, it could explain why the Milky Way has fewer dwarf galaxies orbiting it than expected.

Astronomers came up with dark energy to explain why the expansion of the universe is accelerating. But it has so far only been studied on scales spanning much of the universe.

"Most people think that on shorter distance scales dark energy doesn't do anything," says Stephen Hsu of Michigan State University in East Lansing. At short distances, the other forces – including gravity – should be strong enough to counter dark energy's repulsive influence.

But Hsu and his colleagues wondered how far from the middle of a galaxy you have to go before dark energy takes over. Their calculations show that every galaxy has a critical radius from its centre where the gravitational pull of the galaxy's mass is balanced by dark energy.

For massive galaxies like the Milky Way, this critical radius is 10 times the galaxy's radius, so nothing inside large galaxies would be affected by dark energy. But for dwarf galaxies, the critical radius can be much smaller. (arxiv.org/abs/1501.05952).

This effect could solve a long-standing mystery called the missing satellite problem. Astronomers see far fewer dwarf galaxies orbiting the Milky Way than simulations predict should be there. But according to Hsu's calculations, dark energy should prevent anything from orbiting the Milky Way beyond its critical radius by deflecting the dwarfs before gravity catches them – explaining why no such satellites have been found.

"It's possible that the missing satellite problem is just a manifestation of the fact that there is actually a repulsive force involved," says Hsu. Anil Ananthaswamy ■

Mystery of world's largest seed cracked

THE coco de mer palm of the Seychelles is the stuff of legend. How does a plant that grows in poor quality soil on just two islands produce record-breaking seeds that reach half a metre in diameter and can weigh around 25 kilograms? The answer seems to lie in sacrificing foliage for fruit – and nurturing its seedlings with rain-washed nutrients.

Its seeds – the largest and heaviest in the world – were once believed to grow on trees under the waves of the Indian Ocean, and to hold great healing powers. Even when it turned out that the palm grows on land, new folklore emerged: to produce this seed, the male and female plants embraced each other on a stormy night.

To find out the plant's secret, Christopher Kaiser-Bunbury at the Technical University of Darmstadt in Germany and his colleagues analysed leaf, trunk, flower and nut samples taken from coco de mer palms (*Lodoicea maldivica*) on the island of Praslin.

They found that the leaves have only about one-third of the nitrogen and phosphorus contained in the leaves of other trees and shrubs growing on the Seychelles. Also, before old leaves are shed, the palm efficiently extracts most of their nutrients and recycles them. Investing so little in the foliage allows the palm to invest more in its fruit (*New Phytologist*, doi.org/zx5).

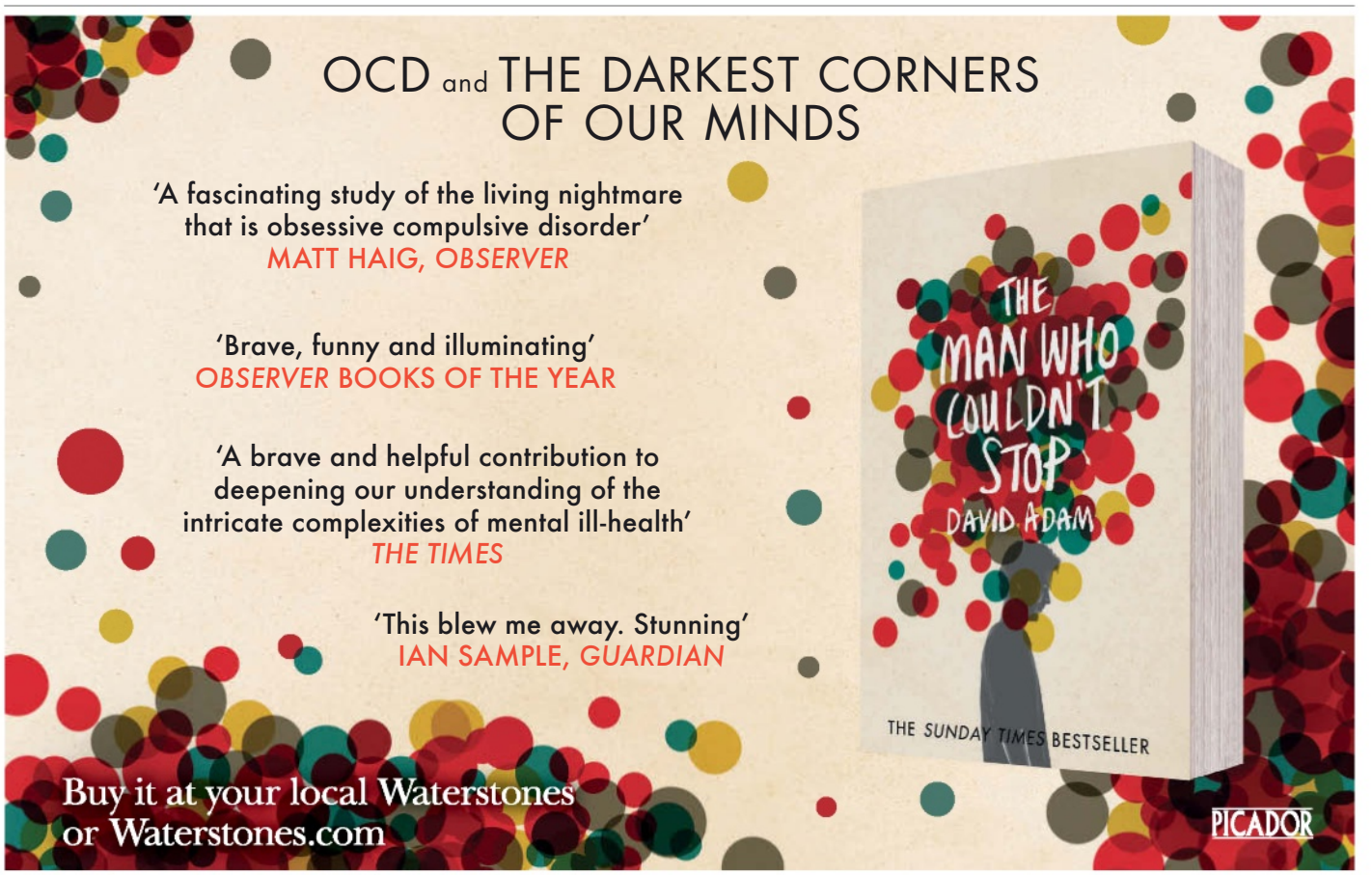
The huge, pleated leaves are also remarkably effective at funnelling rainwater down the trunk. Kaiser-Bunbury and his colleagues found that this stream of water also picked up any nutrient-rich detritus on the leaves – dead flowers, pollen, bird faeces and more – and washed it down into the soil around the base of the palm. That meant the nitrogen and phosphorus concentrations in the soil 20 centimetres from the trunk were at least 50 per cent higher than in the soil just 2 metres away.

VOGEL/LAIF/CAMERA PRESS

A caring parent

The palm seems to be unique in the plant kingdom in caring for its seedlings, which benefit from growing in the shadow of the parent because they have access to the more nutritious soil there. "We do not know of another [plant] species that does this," says Kaiser-Bunbury.

Kevin Burns at the Victoria University of Wellington, New Zealand, says that the coco de mer palm seems to follow a general evolutionary pattern. "Plants tend to evolve large seeds after they colonise isolated islands," he says. "Big seeds generally house more competitive seedlings." **Colin Barras** ■



INSIGHT West African epidemic

Ebola's retreat thwarts drug and vaccine trials

Debora MacKenzie

WE MAY have lost a historic chance to test drugs and vaccines against the Ebola virus, which could leave us without the weapons to prevent the next outbreak.

The epidemic in West Africa prompted an unprecedented rush of clinical trials. But some are now being abandoned and others may produce few clear results, because the steep fall in the number of Ebola cases makes it difficult to test whether the drugs work in enough cases for statistically valid trials.

The fall in cases means the epidemic is entering a new, difficult phase. Last week, the number of people with Ebola rebounded across the affected region for the first time this year, possibly because controls were relaxed too soon. Until every last case is contained, the UN warns that another massive flare-up is a real risk.

No one is complaining that last year's exponential rise in Ebola cases did not continue. David Fisman of the University of Toronto, Canada, says something slowed disease transmission in November, possibly ordinary people taking more precautions. Factoring that into epidemic models "nicely predicts" what is happening now, he says. "We think the epidemic is peaking now, or peaked in mid-January. We project around 35,000 reported cases in total" – far short of the million feared in September.

But there is a downside. It has never been possible to test treatments for Ebola in humans as outbreaks were small and over too fast. This time, clinical trials have begun, but may not be completed because of the decrease in cases. US firm Chimerix has abandoned all Ebola trials for the drug brincidofovir, after case numbers in Liberia fell. Meanwhile, preliminary results were leaked last week from trials of the drug favipiravir, owned by Japan's Fujifilm. Death rates among patients with "low to moderate" levels of the virus fell from 30 to 15 per cent, said reports – but the sample size is too small to draw a conclusion, says Annick Antierens of Médecins Sans Frontières. It is also not clear whether the patients were in the early stages of Ebola, or recovering. The full study will be released later this month.

Lack of numbers could also stymie vaccine giants Merck and GlaxoSmithKline, which last week started giving one of their two experimental Ebola vaccines or a control vaccine to 30,000 volunteers – who will then be watched for Ebola. The decline in cases means the trial may never reach a conclusion, says GSK spokeswoman Aoife Pauley.

The irony of defeating Ebola just in time to prevent tests that could stop the next epidemic is not lost on researchers. The trials were designed and approved in months rather than the years it usually takes – but that's still not soon enough, says Jake Dunning of Imperial College London, who hopes to launch a trial of an RNA-based anti-Ebola drug in Sierra Leone next week.

We may be left with aborted trials and scattered observations of the handful of drugs that have been tried on patients, he says – and they cannot prove whether any treatment will protect us when Ebola explodes again. ■

JOHN MOORE/GETTY

Will the drugs work?

First stars get 150 million years younger

THEY'RE old but not that old. The first stars were born nearly 150 million years later than we thought, according to new data from the European Space Agency's Planck space telescope.

Planck spent three years – between 2009 and 2012 – measuring the cosmic microwave background (CMB). This is the first light released in the universe, 380,000 years after the big bang 13.8 billion years ago. It is leftover radiation released as the hot and dense universe cooled, and is now spread across the entire sky.

At the end of its mission, the Planck team released the highest-resolution map ever of the CMB's temperature, revealing new measurements of all kinds of cosmological details.

Since then, the Planck team has been analysing readings of the CMB's polarisation, which provides another way to study this light. "It's like having an independent experiment to confirm our results," says project scientist Jan Tauber.

One major finding is that a period called the cosmic dark ages lasted longer than we thought. After the CMB was released, the universe was dominated by a fog of opaque hydrogen gas. It stayed dark for hundreds of millions of years until gravity clumped matter together into the first stars and galaxies, which produced enough radiation to ionise the hydrogen and make it transparent.

Astronomers are still short on details about how this lighter period, known as the reionisation era, began and ended. Planck's predecessor, WMAP, pegged the start of the era to about 420 million years after the big bang, but simulations suggested that wouldn't give gravity enough time to work its magic and produce stars.

"Planck, like a cosmic bouncer scrutinising a fake ID, has decided that the dates don't add up"

Now Planck, like a cosmic bouncer scrutinising a fake ID, has decided that the dates don't add up. It has pushed back the start of reionisation to about 550 million years after the big bang, making the first stars younger by nearly 150 million years.

"If the problem had not been resolved, we would have had to think of weird ways to start the formation of stars," says Tauber. Jacob Aron ■

DNA in glass – the ultimate archive

Jacob Aron

IF YOU must preserve messages for people in the far future to read, Blu-ray discs and USB sticks are no good. For real long-term storage, you want a DNA time capsule.

Just 1 gram of DNA is theoretically capable of holding 455 exabytes – enough for all the data held by Google, Facebook and every other major tech company, with room to spare. It's also incredibly durable: DNA has been extracted and sequenced from 700,000-year-old horse bones. But conditions have to be right for it to last.

"It's very important that we get a relatively neutral documentation of our current time and store it"

"We know that if you just store it lying around, you lose information," says Robert Grass of the Swiss Federal Institute of Technology in Zurich. So he and colleagues are working on ways to increase DNA's longevity, with the aim of storing data for thousands or millions of years.

They began by looking at the way information is encoded on a DNA strand. The simplest method treats the DNA bases A and C as a "0" and G and T as a "1". Of course, any damage to the DNA leaves holes in the data, so the team used an error-correcting technique called a Reed-Solomon code. This includes redundant blocks that can be used to reconstruct garbled bits of data.

They also tried to mimic the way fossils keep a DNA sequence intact. Excluding all water from the environment was key, so they encapsulated the DNA in microscopic spheres of glass.

To test how long this storage system might last, they encoded two venerable documents, totalling 83 kilobytes: the Swiss federal charter from 1291, and the Archimedes Palimpsest, a 10th-century version of ancient Greek texts. DNA versions of these texts were kept at 60, 65 and 70 °C for a week to simulate ageing. They remained readable without any errors (*Angewandte Chemie*, doi.org/f23gmf).

The results suggest that data in DNA form could last 2000 years if kept at a temperature of around 10 °C. The Global Seed Vault in the Arctic could preserve it for over 2 million years at a chilly -18 °C, offering truly long-term storage.

Grass would like to store all the world's current knowledge for future generations, but it's far too expensive to generate DNA at present. It cost around £1000 to encode the 83 kilobytes, so doing the same with Wikipedia would run to billions. Instead, Grass suggests that we focus on what future historians might want to read. "If you look at how we look at the Middle Ages, it's very influenced by what information has been stored," he says. "It's very important that we get a relatively neutral documentation of our current time and store that."

Sriram Kosuri of the University of California, Los Angeles, thinks the projected preservation times are reasonable. In 2012 he stored a copy of a colleague's book in DNA and is now working with the band OK Go to create a DNA version of their latest album. But he's less sure about what to put in a time capsule. "I haven't given it much thought," he says. "We pretty much chose an arbitrary piece of digital information whose only constraint is that we weren't going to get in trouble for making a lot of copies of it." ■

JIM RICHARDSON/NATIONAL GEOGRAPHIC CREATIVE

One molecule could downsize it all

Can our online lives be private?

Monday 23 February 2015, 6.30pm

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Melting ice caps could lead to more volcanic eruptions

LESS ice, more lava? Earth's crust falls and rises as ice caps grow and melt – each raising the risk of volcanism.

Kathleen Compton at the University of Arizona and her team analysed data from GPS receivers attached to rocks in Iceland since 1995. They show that areas where five of the country's largest glaciers are melting have been rising by around 3.5 centimetres a year. Rates elsewhere were much lower (*Geophysical Research Letters*, doi.org/zzk). They think the loss of ice is relieving pressure on rocks beneath and allowing them to spring up. Some fear that this could trigger more volcanoes. During the last great melt 12,000 years ago, volcanic activity on Iceland was up to 50 times greater than over the past century, says Bill McGuire at University College London.

Another study reinforces the link between climate and volcanism. John Crowley at the University of Oxford and his team found that huge eruptions in the Southern Ocean coincided with ice ages. By locking up much of the world's water in ice sheets on land, they reduced the ocean's pressure on the seabed enough to allow magma to escape from Earth's mantle (*Science*, doi.org/zzm).

So it seems glaciation can trigger submarine eruptions, while deglaciation may lead to magma outflows on land. Both studies reinforce the idea that redistribution of water caused by climate change can elicit volcanic eruptions, says McGuire.

Are you reading this aloud in your head?

"DON'T think about green jelly." Struggling to get the thought of a wobbling green blob out of your head? You're not alone. Our stream of consciousness turns out to be easily swayed by external influences.

Your inner thoughts may often seem whimsical and isolated, but they're not – something the advertising industry knows all too well. But how many unintended thoughts can you plant in someone's mind at once?

To investigate, Ezequiel Morsella at San Francisco State University and his colleagues showed volunteers a series of 52 black-and-white images of familiar objects. Beforehand, volunteers were asked not to think of the name of the object, nor count how many letters the word had. If they failed, they were told to hit a specified key.

On average, 73 per cent of volunteers said the word in their head, 33 per cent counted its letters and 30 per cent did both (*Consciousness and Cognition*, doi.org/zx9). "We are predicting and controlling not one, but a sequence of thoughts, and each one stems from a very distinct and high-level process," says Morsella. "We're beginning to realise that conscious processes are a lot more like reflexes."

Glass ceiling model shows cracks below

EQUALITY at the bottom of the corporate ladder might be better at smashing the glass ceiling that holds back female advancement than quotas in the boardroom, a mathematical model suggests.

Barbara Keller of the Swiss Federal Institute of Technology in Zurich and her colleagues modelled PhD students' choice of mentor to see if a glass ceiling effect emerged in the resulting social network. They used three assumptions that reflect the real world: there is a gender imbalance among PhD candidates, students choose mentors who already have lots of students, and they choose mentors of their own gender.

Female mentors attracted fewer students than did male mentors. But if any one assumption was removed, the effect disappeared. So bringing more women into fields dominated by men might crack the glass ceiling on its own, says Keller.

Magic number breaks up acid

IT SOUNDS like a bad physics joke: how many water molecules does it take to change an acid? But what happens when an acid falls apart in water is a mystery.

When its bonds finally break,the acid must give up a proton to the water. To find out precisely when, Vitaly Kresin of the University of Southern California in Los Angeles blasted water vapour through a pinhole and added hydrochloric acid to the spray. Then they measured how much the water-acid clusters were deflected by an electric field, to see if the acid was intact.

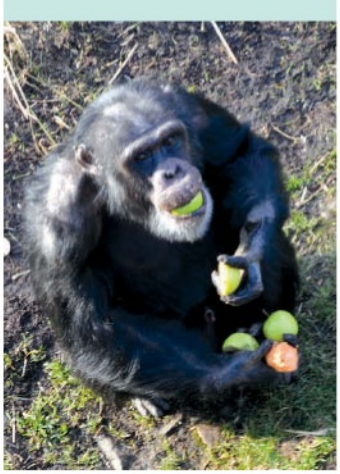
Five to six water molecules seem to be enough to split one acid molecule asunder, the team found (*Physical Review Letters*, doi.org/zzq).

Chimps can learn new language

AN OPENING for Google Transl-ape? Chimpanzees can learn to grunt "apple" in two chimp languages – a finding that calls into question how unique our own language ability is.

Katie Slocombe of the University of York, UK, and her team recorded vocalisations by a group of adult chimps from the Netherlands before and after their relocation to Edinburgh Zoo. Three years after the move, the Dutch chimps had picked up the pronunciation of their Scottish hosts. The peak frequencies of the Dutch chimps' shrill calls fell from 932 to 708 hertz to match closely with the low-toned grunts of the Scottish apes (*Current Biology*, doi.org/zzd). The change was gradual and coincided with the growing friendship of the two groups. This means that, like us, chimps can learn foreign lingo to fit in with new neighbours.

The finding also challenges the prevailing theory that chimp words for objects are fixed because they result from excited, involuntary outbursts. The assumption was that animals do not have control over the sounds they make, whereas we learn the labels for things socially – which is what separates us from animals, says Slocombe. But this may be wrong, it seems. "It's the first time call structure has been dissociated from emotional outbursts," she says.



EMMA K WALLACE

Musical software ups the tempo during birth

PUSH! It's a familiar instruction to women giving birth, and an important one for those on body-numbing drugs. Epidurals and spinal injections can make it a struggle for women to push their baby out. But a new device that signals the baby's progress can help women to learn when and how to push, speeding up labour and reducing the risk of problems.

Pain-blocking drugs are given to about one-third of women giving birth in the UK, and are known to prolong labour. The longer the duration of the pushing stage, the higher the likelihood of adverse outcomes, such as perineal tears, infection or the need for forceps delivery. This is because the drugs dampen nerve signals, which can reduce cues from the body to push.

M. Bardett Fausett at the Women's and Children's Hospital in Lafayette, Louisiana, and his colleagues have developed a device that effectively tells women in labour how well they are pushing. Electrodes on the baby's head and the mother's perineum are connected to laptop software that signals the baby's movement: a successful push is marked with a graph spike and an ascending musical tone – the tempo of which matches the outward movement of the baby.

In a trial of 45 women who used the device and 24 who did not, Fausett's team found the average duration of the pushing stage of labour dropped from 77 to 58 minutes for those trying the software, and adverse outcomes were reduced. "The patients and their families loved it," says Fausett.

Pluto's pockmarks evaporate quickly

PLUTO has a blank face. It seems that the dwarf planet's nitrogen-rich ice evaporates faster than realised, disappointing those who hoped its pockmarks could keep a census of the outer solar system.

Thousands of icy bodies orbit the sun in a ring beyond Neptune known as the Kuiper belt, but many are too small to observe from Earth. Planetary scientists had hoped that when the New Horizons spacecraft speeds past Pluto in July, its images of the scarred surface could help snoop on the neighbours: the more small craters Pluto has, the more small bodies in the Kuiper belt.

But Simon Porter at the Southwest Research Institute in Boulder, Colorado, and colleagues have calculated that because Pluto loses between 10^{27} and 10^{28} nitrogen molecules a second, it should have lost between 0.3 and 3 kilometres of ice over 3.5 billion years, erasing much of the small crater record (*Icarus*, doi.org/zx4).

There's hope, though: Pluto's ices also contain methane, which preserves craters better than nitrogen. In addition, Pluto's largest moon Charon is covered with hard water ice, and so should preserve a pristine impact record.

ALEKSANDAR SIMOVIC

Cannibal lizards turn utopia into hell

A SUNNY Greek island bursting with food and without a predator in sight sounds like heaven. But for young lizards it is more of a nightmare – full of super-sized cannibals after them.

"Cannibalising youngsters is an effective way to get rid of future rivals and at the same time get a nutritious meal," says Panayiotis Pafilis at the University of Athens in Greece.

Lack of predators and plenty of food means wall lizards on the tiny Greek island of Diavates in the Aegean Sea balloon to up to three times their weight elsewhere – but it also makes the island crowded.

Previous research found that adult Diavates lizards were some 20 times more likely to have juvenile body parts in their stomach than lizards on the neighbouring island of Skyros, where predatory snakes, mammals and birds keep the population in check.

To find out more, Pafilis's team placed a hungry adult in an enclosure with a youngster. Over two-thirds of the Diavates lizards attacked the juvenile, compared with 17 per cent of Skyros lizards. The waiting period before attacking was also nearly six times shorter for the Diavates lizards (*Ethology*, doi.org/zzf).

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Driverless cars in gridlock

There are four problems holding up autonomous vehicles, says **Hal Hodson**. How can we fix them?

RINSPEED XCHANGE

SOME day soon, driverless podcars will cluster around our cities, waiting to pick us up on demand. There will be no steering wheel, no brake pedal; once seated, you can take a nap or watch a movie. This public facility will reduce traffic and carbon emissions. Not having to own a car will make transport cheaper for everyone.

Stop us if you've heard this one before.

Why are self-driving cars taking so long to show? For starters, essential technological and social changes needed to make them work might still be decades away. But they are on their way, thanks to some of the world's largest companies. Google has been fine-tuning its autonomous cars for years, amassing hundreds of thousands of kilometres of test drives on Nevada's roads. Last week the developers of the taxi app Uber announced a collaboration with Carnegie Mellon University's Robotics Institute to develop technology for a self-driving taxi fleet.

"California's sunny roads are great, but when it's wet and misty cars miss turns and mount the kerb"

"It's a very big deal," says Nidhi Kalra, an analyst at the RAND Corporation. "Nearly every auto-maker is pursuing this technology."

So what are the remaining obstacles, and how close are we to overcoming them?

PROBLEM 1

COPING WITH HUMANS

Autonomous cars will confront the same problem that faces all robots designed to operate around people: social interactions are a key part of negotiating our world.

Self-driving cars must be able to navigate situations where drivers rely on eye contact: merging into a busy stream of cars, following the directions of traffic police, allowing another car to pull out in front of them, coping with crowds of people on the street.

They must also be able to interact with their passengers. Semi-autonomous cars must detect if their drivers are nodding off during long stretches of autonomous driving, and then be able to rouse them back into paying attention.

This transition between human and software control, known as the handoff problem, is a big challenge in automating all kinds of processes. The crash of Air France flight 447 in the Atlantic Ocean in 2009 was the result of the crew responding incorrectly when the autopilot suddenly handed control to them.

HOW CLOSE ARE WE?

Human-robot interaction is hard, and our ability to do tests in this area is limited by the number of robots already out there performing real-world tasks.

Giving cars the kind of social intelligence displayed by Jibo, a robot designed for domestic use (*New Scientist*, 19 July 2014, p 21) could help them navigate our world safely. The other option is to make the system completely autonomous. This already happens in self-driving trains the world over, the first example of which was launched in Japan in 1981. Trains are much easier to automate because they are constrained to travel on tracks, and there's no need to interact with other train drivers. To be truly useful though, self-driving cars ought to be just as woven into our lives as existing vehicles, maybe more so. How that will work is still up for debate.

DIFFICULTY RATING

PROBLEM 2

THE WEATHER

California's sunny highways are great for Google's self-driving car. But how would it have fared in the snowstorms that hit the US east coast earlier this month, or in protracted drizzle in London?

Badly, is the answer. A self-driving car competition hosted by Hyundai in South Korea last year provides a perfect example. On the first day of the competition, the cars handled the track and obstacles at speed with few mistakes in dry, clear conditions.

The following day was wet and misty, and the same cars missed turns on the course, veered into the opposing lane and mounted the kerb. Machine vision systems that use ordinary cameras can't see as well in these conditions, and this trips up the cars' navigation software.

HOW CLOSE ARE WE?

Equipping cars with a wider array of sensors, as well as embedding sensors into the environment, will help. In particular, cars can be fitted with devices to tap into regions of the spectrum that cut

Dream journey

better through fog or rain. "I don't see weather as the showstopper that people are talking about," says Kalra.

Testing the cars in more challenging climates than Silicon Valley's will help, too. To that end, the University of Michigan is building a 13-hectare test site to put cars through their paces in the rain, sleet and snow of the Midwest. Communication between cars and roadside sensors will be one of the lab's main focuses, as weather conditions can't throw this out so easily.

DIFFICULTY RATING

PROBLEM 3

SECURITY

It's one thing for a virus to cause your phone or laptop to crash, but if the same fate befalls a driverless car, the consequences will be much more dramatic.

Any software bugs in an autonomous car might let a hacker take control of the vehicle remotely, perhaps locking the passengers inside until a ransom is paid. Car companies will probably pore over their software more intently than the average app developer, but they will still miss things. When problems crop up, they will need to fix them as fast as possible. It should also require minimum effort by the user, as the hassle of dealer visits means passengers may settle for cars with unpatched software.

HOW CLOSE ARE WE?

Tesla cars, the most internet-connected make available, provide a model for security. After a Tesla crash in Mexico resulted in a battery fire, Tesla pushed a software update to every one of their cars. This made the suspension ride a little further off the ground when travelling at speed, lowering the risk of road debris damaging the battery. That ability to push updates will be valuable in quickly patching bugs in self-driving cars' software.

DIFFICULTY RATING

PROBLEM 4

LEGAL AND PERSONAL

To persuade society at large to put lives in the hands of autonomous cars, their makers will have to show that the cars are at least as safe as conventional vehicles. This presents a problem. To demonstrate equivalent safety for self-driving cars in a statistically relevant way, the Googles and Audis of the world will need to cover billions of miles autonomously, unfeasible without mass adoption.

The details of insuring driverless cars are yet to be worked out too. Google put up enormous bonds of between $1 million and $3 million to test its vehicles in Nevada. And there's a host of niggling legal issues to be straightened out: for instance, laws that require cars to have a steering wheel or an accelerator of a certain size.

HOW CLOSE ARE WE?

Kalra suggests that the safety message really has to be the priority for makers of autonomous cars. If their cars are proven to experience fewer crashes in situations that are likely to lead to accidents when humans are driving, their case will be stronger. Even so, the risk will still be high at first. These factors may mean that freight vehicles become automated ahead of human transport, as the loss of human life presents a far larger risk to companies than damage to goods. You're more likely to be overtaken by an autonomous truck than to be driven by one, at least for now. ■

DIFFICULTY RATING

ONE PER CENT

Satellites via plane

Forget rockets. DARPA, the research arm of the US Department of Defense, wants to send satellites into orbit from the back of a plane. Project Airborne Launch should cost less than $1 million per launch, about 500 times cheaper than the space shuttle. A plane will fly as high as it can before releasing a vehicle that can carry 45 kilograms into space. The first launch is expected early next year.

"We suck at dealing with abuse and trolls on the platform and we've sucked at it for years"

Twitter chief executive **Dick Costolo** admits that his company must do more to deal with online abuse, in a leaked memo obtained by technology website The Verge

Unleash the drones

One nation, under drones. A poll released last week by Reuters/Ipsos found that many Americans are warming to the idea of drones in everyday life. More than 60 per cent said they would be OK with police officers flying drones to deter crime, and 49 per cent would let parents use them to keep tabs on their kids. However, 64 per cent also said they wouldn't want their neighbour to have one.

DARPA

Naval firefighting robot hoses down its first blaze

THE robot looked on as a fire burned aboard the USS Shadwell, its eyes scanning for the heart of the blaze. Then it grabbed a hose and started spraying water into the inferno.

Staged in Mobile, Alabama, this was the first live test of SAFFiR – the Shipboard Autonomous Firefighting Robot – and the first time any robot has fought a fire. SAFFiR was developed at Virginia Polytechnic Institute in Blacksburg for the US navy, and could one day be installed on every navy ship, tackling fires without risking human life.

With a mass of 65 kilograms and standing 178 centimetres tall, SAFFiR uses dual optical cameras to see, thermal cameras to peer through smoke and find fires, and laser sensors to gauge distances. Although it can walk and pick up a hose on its own, all other actions are controlled by a human operator.

Thomas McKenna of the Office of Naval Research announced this week that the navy wants to fund the next version of SAFFiR, which will have improved battery life and software.

He also foresees SAFFiR becoming a multipurpose robot. "We have taken a look at other kinds of sensors that you can put on these robots," he said. "A bipedal robot could be configured to take shipboard measurements, and scan for corrosion and leaks."

Hal Hodson ■

JOHN F. WILLIAMS/U.S. NAVY PHOTO

Sure-fire success

CHRIS MADDALONI/GETTY

Tech takes on tradition

Hackathon invents the tools to fix Congress

Aviva Rutkin

THINK of the US Congress, and the term "high-tech" is unlikely to come to mind. The US government is derided for being slow, out of touch and desperately behind the times. Now it is getting a long overdue digital boost via a favourite tool of the tech community: hackathons.

Last weekend, I went to the Harvard Kennedy Center in Cambridge, Massachusetts, which was hosting the first of three hackathons focused on finding modern solutions to intractable political problems, such as how parties raise money and the deep divide between Republicans and Democrats. Eventually, the top teams will travel to Washington DC to present their ideas to members of Congress.

It's an unconventional approach, admits Seamus Kraft of the OpenGov Foundation, a DC-based non-profit organisation that helped to put on the event. But he insists that it can bring a sense of urgency and a fresh set of skills to a government deeply in need of innovation.

"People inside Congress are inundated or tradition-bound, and they just don't know there's a better way," he says. "Through Hack4Congress, we can show that there are lternatives – they're here, they're real and, most importantly, there are people who are willing to help."

"My favourite idea was a reality TV show through which viewers could follow aspirant politicians"

At a panel discussion, I heard experts – including a former congressman – describe the issues currently plaguing Congress, including overworked staff, partisanship and low levels of citizen participation.

Attendees had a day and a half to come up with viable solutions. One team built an online tool that would allow congressional committee members to hold virtual hearings that are open to the public. Another group suggested a radical redesign to Congress's internal communication system, making it easier for representatives to collaborate, search through archives and use analytics to find patterns. Yet another team built an app that lets officials quickly survey their constituents through push notifications.

My favourite idea was a reality TV show called *The Candidate*, through which viewers could follow aspirant politicians in local elections and support them through a crowdfunding website. The pitch read: "Think *American Idol* meets YouTube meets Kickstarter meets politics."

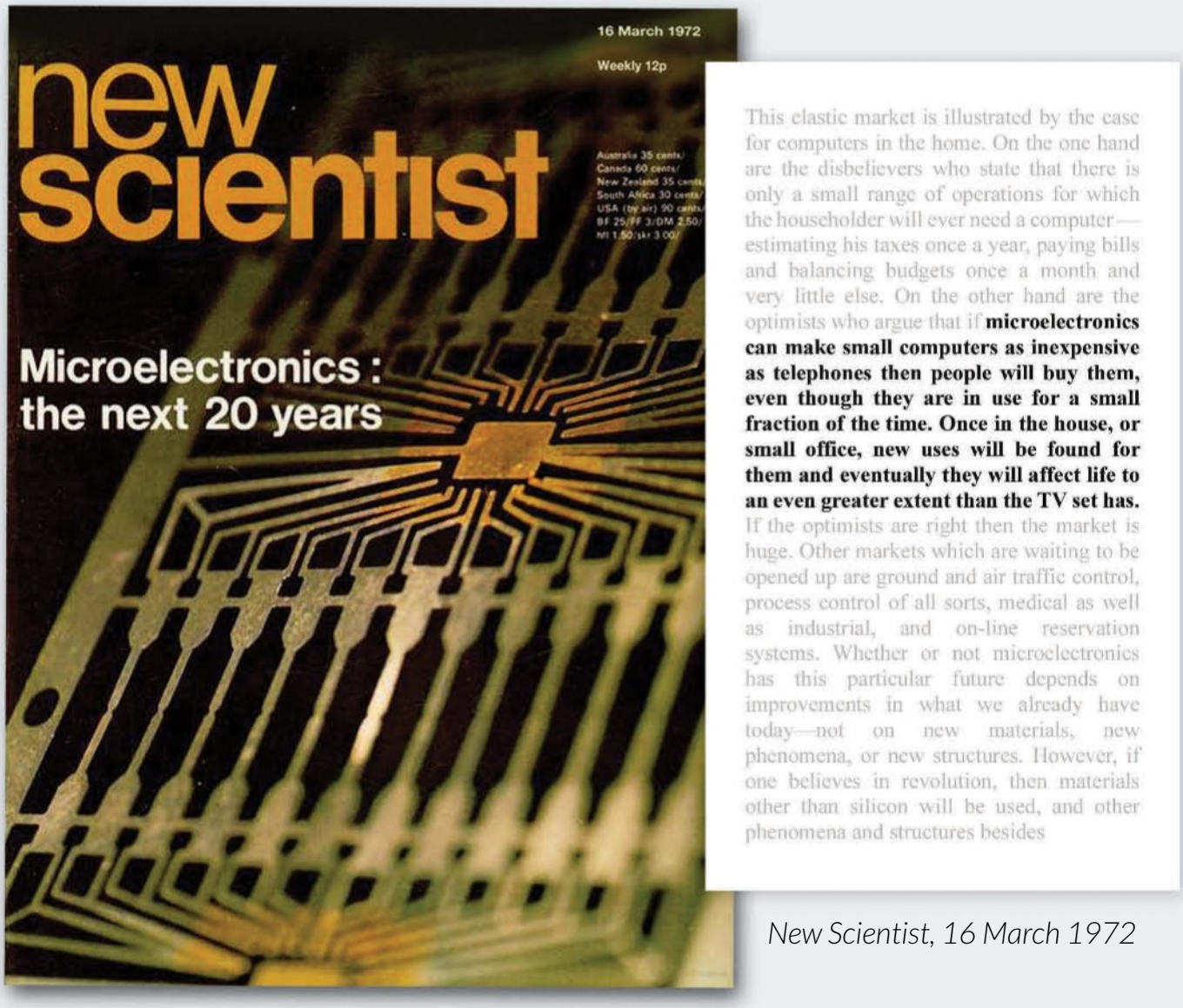
But the winner of the weekend was Congress Connect, an online platform that helps ordinary citizens arrange meetings with their representatives. The site also offers tutorials on how to prepare for meetings and helps the public to find like-minded voters through social media.

"A lot of discussion around fixing Congress is about getting representatives to be more responsive to constituents and less responsive to lobbyists and money," says Chris Baily, an interactive designer in New York and a member of the Congress Connect team.

Baily's team will demonstrate their idea for Congress in May, alongside the winners of further congressional hackathons planned in San Francisco and Washington DC.

The hackathons are part of a larger trend. Last summer, the White House launched the US Digital Service, a department dedicated to improving government by building better websites and improving data sharing between agencies. ■

For forward thinkers



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RESIN

Waste not, want not

THERE is an air of contentment about the scene, of a responsible job proudly and diligently done. Yet these women in Guiyu, a cluster of villages on the south China coast, are doing some of the world's dirtiest work: recycling electronic waste.

Laptops, smartphones, microwaves and fridges contain a cocktail of valuable elements in their circuits and casings, among them copper, gold, silver and lead (see page 35). It's bounty enough to keep an estimated 3000 workshops in Guiyu busy, extracting the raw materials to sell on.

Much of the e-waste is the product of China's domestic electronics boom, with over 7 million tonnes created in 2012. But shipments from the US, Australia and Europe regularly circumvent an import ban instituted in 2000.

The cost to the environment and human health is high: run-off from acid baths used to strip out metals has entered watercourses, while burning off plastics has fouled the air. Neurotoxic PCBs have been found in fish, and children in the area have unusually high levels of lead in their blood.

Since 2007, a UN initiative called StEP – Solving the E-waste Problem – has coordinated efforts to stem the flow of e-waste by encouraging manufacturers to remove the most harmful chemicals from their products and creating and maintaining more formal recycling streams. Too late, perhaps, for the ladies of Guiyu. Richard Webb

Photographer
Kai Loeffelbein/Laif/Camera Press
kailoeffelbein.com

Crossing the germ line

After permitting three-parent babies, let's stop drawing lines in the sand and talk about genetically engineering everybody, says **Michael Le Page**

WANT to see what a genetically modified human looks like? Just glance in the mirror. You are the result of an experiment that randomly modified your DNA in at least 50 places.

No ethics committee in the world would approve such a dangerous practice. But hey, it's OK because the scientist in this case is nature. And nature is good, right? Never mind that some unlucky kids die horrible deaths because they end up with cruel and fatal mutations. Never mind that just about every one of us will suffer at some point in our lives because of the legacy of countless generations of this uncontrolled experiment.

What if we could put a stop to this? We have already begun in a small way. For the past three decades some communities have been screening would-be parents to ensure their children do not inherit one particularly cruel genetic modification – Tay-Sachs disease. More recently, we have begun to screen IVF embryos before they are implanted in cases when we know children risk inheriting one or other of the nastiest results of nature's meddling, such as cystic fibrosis.

And now, with the UK parliament's vote in favour of three-parent babies, we are about to go a step further and actively replace damaged genes with working versions. These will be passed on to subsequent generations, breaking the chain of a range of inherited diseases. Great! This form of genetic engineering should end much suffering. But wait! Gasp!

Did I write the e-word? I'm sorry, what I meant was "mitochondrial donation".

The decision to allow three-parent babies is right. But the fact is, opponents were also right to describe this as a step towards tinkering with the rest of our genome. Most supporters seemed to have convinced themselves otherwise, but let's look at the arguments used.

One is that mitochondrial replacement is no big deal because mitochondria contain just 37 of the 23,000 or so human genes. Sure, but most genetically modified plants and animals have only one or two altered genes. If replacing genes is OK as long as it's only a small proportion, you could justify quite substantial alterations this way.

Ah, we are told, but the point is that these 37 genes do not affect children's character or appearance. The "only known traits" that could come from the mitochondrial DNA concern energy production, proponents of the technique have argued in *New Scientist*.

Fine. But most of our 23,000 genes are involved in fundamental processes such as cell division, and do not have any known effects on our character. So by this logic, it is OK to tinker with most of our genes.

"With technology advancing fast, it is time to challenge the idea that our genomes are inviolable"

Of course, replacing faulty mitochondria, which are self-contained organelles within the cell, is relatively simple and – we think – safe. Replacing or altering genes in the cell nucleus is much trickier. It involves editing DNA by cutting and pasting bits of it – recombinant DNA technology – and it is not safe at the moment. It would be utterly wrong to attempt to do this in people with the existing technology.

But the technology is advancing at a breathtaking pace. We're getting much better at editing DNA, with the help of easier and more precise techniques such as CRISPR, and we can now check those changes with whole-genome sequencing. It could be just decades before it is safe to attempt germ-line genetic engineering using recombinant DNA technology.

Even without the religious and historical objections, germ-line alteration remains a taboo to many. They regard our genome as somehow special, something we shouldn't mess with. In reality, our genomes are a mess.

Yes, evolution has produced many marvels, including us. But it succeeds only by making countless mistakes. The worst of these genetic mistakes die with the children landed with them. Less serious mistakes, or those that only kill late in life such as the neurodegenerative disease Huntington's, may never be eliminated by nature.

All of us inherit a host of less obvious harmful mutations. Perhaps you are more likely to suffer from heart disease, certain cancers, dementia or mental illnesses, or to lose your sight or go deaf in old age. And your children and your children's children and all their descendants will inherit many of these mutations, along with the new ones produced as nature's random errors continue.

When you understand how these mutations come about, the case for taking charge of our genetic destiny seems unanswerable. We are acquiring the ability to free ourselves from the baggage of 4 billion years of mindless evolution.

Germ-line genetic engineering clearly has dangers, not least its potential to be used for the wrong purposes or the potential for its cost to restrict its advantages to the wealthy. But many worries are exaggerated – we couldn't engineer Einsteins if we wanted to, for instance, because we haven't found any gene variants that make a notable difference to intelligence, despite much trying.

What we could do is end a tremendous amount of suffering. And if it is available to everyone, not just the rich, genetic engineering could even help make the world a much fairer place – illness keeps many in poverty.

I suspect many biologists harbour similar views, but not many say so openly. Instead, they back three-parent babies but say it isn't really genetic engineering.

This might be politically expedient in the short term. But with technology advancing with dizzying speed, it is time to challenge the idea that our genomes are somehow special and inviolable. We can do better than mindless evolution. And for the sake of our children, we should do so as soon as we safely can. ■

Michael Le Page is a features editor at *New Scientist*

ONE MINUTE INTERVIEW

The tornado in a bottle

The wind tunnel has evolved – we can create twisters and other phenomena at the touch of a button, says **Maryam Refan**

PROFILE

Maryam Refan is a researcher at the Wind Engineering, Energy and Environment Research Institute (WindEEE) in London, Ontario, Canada. Beyond the lab she has chased – and caught up with – a dozen tornadoes

What is the WindEEE facility?

It's a wind research centre that is very different to conventional wind tunnels. For a start, the wind chamber is a hexagon 25 metres across. In the lower part of the chamber we have 60 fans on one wall and eight directional fans on each of the other five walls, and in the upper chamber are six huge fans. All are individually computer controlled.

What can you do with a set-up like that?

It's very versatile. We can create straight flows, but also rotating ones, to simulate tornadoes and downbursts. To picture a downburst, imagine turning on a tap: the water falls fast and when it hits the sink it spreads out. A similar thing happens with air and it is very dangerous to aircraft.

Tell me about your "tornado in a bottle".

We can create a 5-metre-wide tornado inside the chamber. A tornado is a combination of rotation and suction. By angling the airflow from the fans around the lower chamber we control the rotation of a tornado vortex, and we create the suction by running the six huge fans in reverse. The beauty of our tornado is that we can move it along the ground at 2 metres per second.

Have you tried standing in that swirl?

Yes, but the whole flow is scaled down – the size, the velocity. So if I stand in the vortex it's very, very gusty and hard to keep my balance, but it won't pick me up. With the straight flow, wind speed gets up to about 40 m/s. In tornado mode, 30 m/s.

How can you tell where the wind is going?

The simplest way is using smoke. We can also put helium-filled soap bubbles in the flow, which are neutrally buoyant, and take pictures to see the flow's behaviour. We have sensor arrays too.

What's been done with WindEEE so far?

We became operational in October, and have so far tested wind loading on full-scale roof-mounted solar panels. We're also looking at the effects of a tornado on buildings: we aim to find out if tornado wind loading should be included in building codes.

What other projects are you running?

We're partnering with the European Union as part of a project called Horizon 2020. Turbines in a wind farm can interact with each other, affecting the airflow between them. We simulate that flow and then model different wind turbines, types of rotor control and so on. It's about extracting as much power as you can from wind turbines.

What do you most enjoy working on?

I've chased real tornadoes, so our tornado is my favourite. But the facility is versatile. For example, we've looked at the effect of downwashes – akin to downbursts – on a remote-controlled airplane.

Have you flown the plane into the tornado?

[Laughs] No. The thing about tornadoes is that you can see them, so pilots don't fly into them. Downbursts can be invisible. But we have the plane, so maybe one day we'll fly it into the tornado and let you know what happens.

Interview by Sean O'Neill

COURTESY OF MARYAM REFAN

The world in a cell

The evolution of complex cells was a critical event for life on Earth. We can explain how it happened, say **David Baum** and **Buzz Baum**

TAKE a walk in the woods and what do you see? Trees reaching skywards with birds in their branches and, at their roots, mushrooms pushing through the leaf litter. These, and all the organisms you can see with the naked eye, have one fundamental similarity. Like us, they are constructed from the same kind of cell. Under the microscope, the differences between plants, animals and fungi fall away to reveal a common internal structure.

The biosphere would be unimaginably different had this "eukaryotic" cell never evolved, making its origin one of the most critical events in the development of life on Earth. Almost everybody agrees that the complex eukaryotic cell evolved from a simple ancestor. The question is how.

Inside the eukaryotic cell is an intricate meshwork of membranes called the endoplasmic reticulum (ER), interspersed with other structures such as the energy-generating mitochondria. At the core is the nucleus, a large compartment with a double membrane, within which lies the cell's genetic material.

"We think complex cells evolved from the inside out, not the outside in"

Take away this type of cellular organisation and the only thing left on the planet would be simple cells known as prokaryotes – bacteria, for example – which under a microscope appear as little more than tiny gel-filled sacs.

Biologists have always assumed that the eukaryotic cell evolved when a prokaryote folded parts of its outer membrane inwards, pinching off portions to generate internal compartments. Some membranes, it is imagined, wrapped around the DNA to make the membrane of the nucleus, while others morphed into the ER. And at some time during this process, free-living bacteria are thought to have been engulfed by the rest of the cell in a process akin to swallowing, called phagocytosis. These bacteria went on to become mitochondria. While lots of variants of this model have been developed over the years, all make the implicit assumption that eukaryotes evolved from the outside in – by pulling pieces of external membrane and mitochondria into the cell.

We think this is the wrong way round. In a recent paper, we propose instead that eukaryotic cells evolved from the inside out – that a prokaryote extruded blebs of outer membrane through its cell wall, and these fused to form the peripheral parts of the eukaryotic cell that contain the ER and mitochondria (*BMC Biology*, vol 12, p 76). Like the famous optical illusion in which one can see either two faces or a candlestick, when the eukaryotic cell is viewed afresh from this perspective, many things look different. Now the outer membrane of the eukaryotic cell is an evolutionary novelty, while the nuclear envelope corresponds to the boundary of the original prokaryotic ancestor – the opposite of what is assumed by traditional hypotheses.

Although our inside-out model was published last year, the idea was born some 30 years ago when David was studying botany at the University of Oxford. Looking at an image of a large eukaryotic cell next to a much smaller prokaryotic cell, David wondered why it was always assumed that the boundaries of the two types of cell were equivalent, when it was easy enough to imagine that the prokaryote cell corresponded to the nucleus of the eukaryote. His essay on the topic, written in 1984, described this basic idea. While it got a respectable mark, it did not seem very compelling at the time. For a start, no prokaryote was then known to extrude membrane outwards. David sat on the idea, always thinking that somebody else would come forward with the concept, and his research turned in other directions.

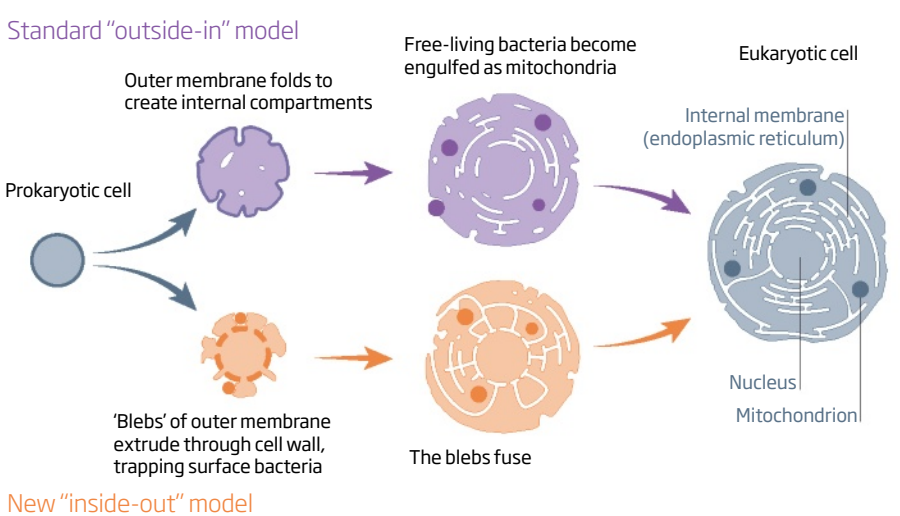
Thirty years later, when David started to think again about the origin and early evolution of life, he was surprised to see that, in the interim, nobody had suggested that complex cells arose in this way. Perhaps it required the naiveté of an undergraduate to question dogma? So David dusted off his inside-out model and wrote up a short piece to explain how it might work and why it ought to be considered as an alternative explanation for the origin of eukaryotes. And it was much more compelling now it is known that the prokaryotes most closely related to eukaryotes, the archaea, often produce extracellular protrusions. As well as friends and colleagues, David sent the essay to his cousin, Buzz.

As a cell biologist working with yeast, flies and human cells, Buzz had long grown

FRANS LANTING/NATIONAL GEOGRAPHIC CREATIVE

Our planet would be vastly different had eukaryotic cells never evolved

The route to complexity



PROFILE
David Baum is an evolutionary biologist at the University of Wisconsin, Madison. **Buzz Baum** is a cell biologist at University College London

accustomed to staring at the elaborate internal structure of eukaryotes but had never heard a convincing explanation for the origin of this dazzling complexity. Maybe the inside-out model could shed light on this, and on other puzzling features of modern eukaryotes too.

We started exchanging drawings made in snatched moments, on napkins and loose sheets of paper, on buses, planes and trains. Looking at these sketches, answers to some unexplained aspects of eukaryotic cell biology seemed to jump off the page: for instance, the model explained why the ER is directly linked to the bounding membrane of the nucleus, and why they both contain chemicals similar to archaeal cell wall components.

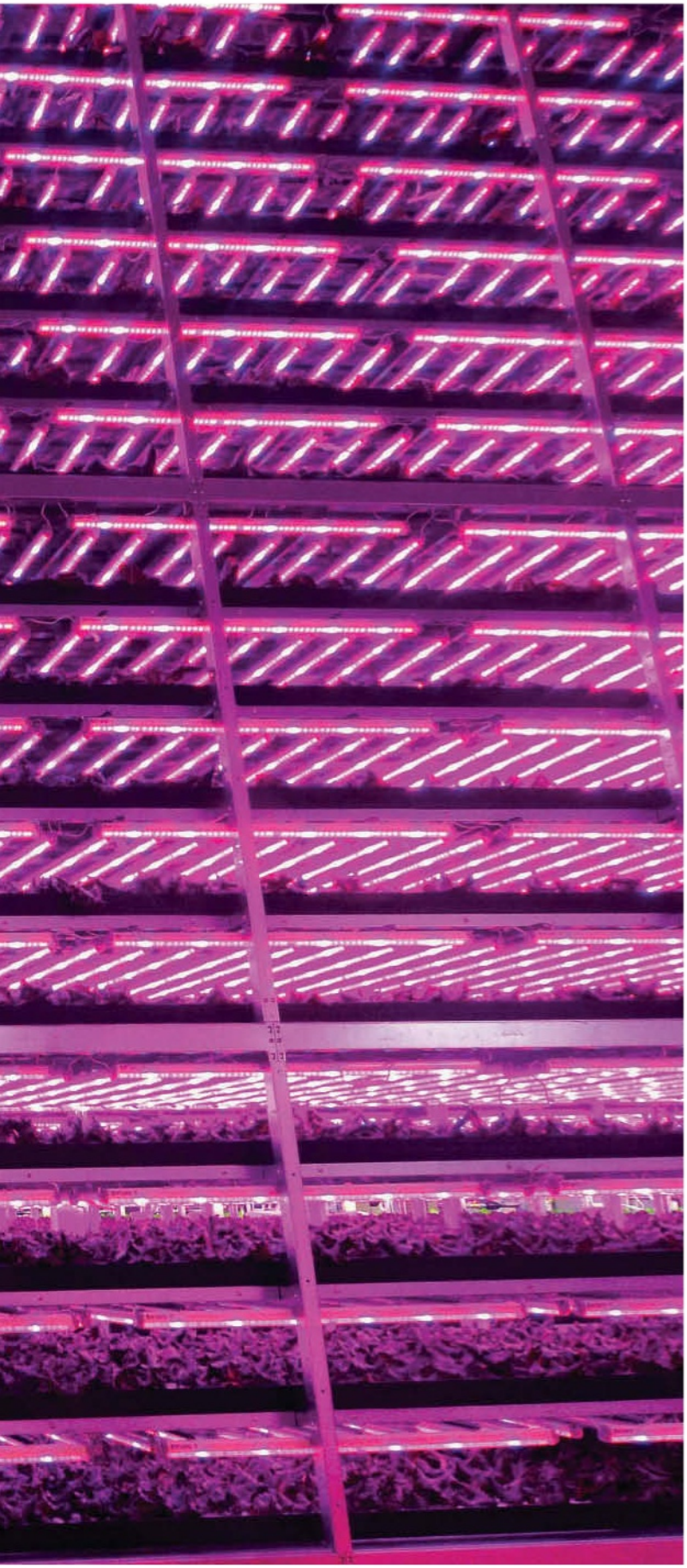
Echoes of the past

The success of this way of thinking got us wondering whether modern cells retain any echoes of their past in the way they work. By thinking about the way cells grew and divided as they evolved into modern eukaryotes, we were able to make some startling predictions for various aspects of cell biology that are currently poorly understood. For instance, the inside-out model suggests a role for the ER in determining the pattern of diffusion of molecules within cells, and predicts functions for several unstudied proteins in archaea.

To test these predictions, Buzz and his students have begun examining the dynamics of diffusion within eukaryotic cells. They will also look at proteins that are shared by eukaryotes and archaea to test their functions and locations within archaeal cells, something that will require overcoming the technical challenge of imaging these cells in sulphuric acid solution at 76 °C, their preferred growth conditions. Meanwhile, David is using computational analysis of various genes to test competing ideas about how the ancestors of mitochondria made a living.

Regardless of whether the inside-out view prevails, testing these ideas will provide a better understanding of how eukaryotes came to be. This may help to explain why eukaryotes evolved just once on Earth and, in so doing, will shape our expectations as to whether other planets might, in addition to microscopic prokaryote-like cells, harbour large and complex organisms such as those that make life on Earth so enchanting. ■

THE ASAHI SHIMBUN/GETTY



Is farming crops under artificial light really the environmentally friendly option? **Michael Le Page** is sceptical

GREEN DREAM

THE red mustard microgreens I'm munching on are fiery and delicious. But their taste isn't what makes them extraordinary. They were grown 30 metres beneath the streets of south London in a second world war bomb shelter.

If commercial production begins later this year as planned, this will become perhaps the most unusual farm in the world. The idea is to grow microgreens and salad plants for London's shops and restaurants. Local food, grown right in the middle of a big city – without ever seeing daylight.

It might sound implausible, but this won't be the first "indoor farm". Around the world, a few small enterprises have already begun growing food entirely under electric lights. Is this the start of something big?

"There is a real trend towards something called variously urban agriculture, indoor farming or vertical farming," says Cary Mitchell, a horticulturist at Purdue University in West Lafayette, Indiana. The original vision for vertical farming was that instead of farms swallowing up ever more land, they could be built upwards. Skyscrapers filled with plants rather than pencil pushers would feed entire cities.

This was never realistic – skyscrapers don't come cheap, for starters – but the idea of urban farming has lived on in various forms. In New York City, a company called Gotham Greens has built several greenhouses on the ›

Stacking plants on electrically lit shelves is a very compact way of growing food

roofs of buildings. One supplies the supermarket beneath it. Trouble is, there aren't that many suitable sites on rooftops, and conventional greenhouses typically use more energy than growing plants in fields – they need cooling in summer, and heating and extra light in winter.

Others are making a somewhat humbler version of the original vertical farming vision a reality. In an industrial warehouse not far from Chicago, for instance, Green Sense Farms has begun growing herbs, microgreens and lettuces in huge, densely spaced racks. A similar facility is up and running in Miyagi Prefecture, Japan (pictured on page 30). The bomb shelter farm in London is the same

"One Japanese farm, with plants in racks 16 deep, is said to be 100 times more productive per square metre than an outdoor farm"

idea in a more unusual location. "It's vertical downwards instead of upwards," says Mitchell.

The advent of LED lighting has made this sunless form of vertical farming possible. High-pressure sodium lights have been used by growers for decades to supplement the dim winter sun. Existing LEDs are no more efficient at converting electricity to light than the latest sodium lights, but crucially are a much less concentrated source of heat. "They can be positioned closer to the plants and allow plant growth on shelves," says Bruce Bugbee of Utah State University in Logan.

This means many more plants can be grown in a small space. The government-subsidised Miyagi farm, where plants grow all year round in racks 16 layers deep, is reportedly 100 times more productive per square metre of land than an outdoor farm.

"Without LEDs, this would not be viable," says Steven Dring, one of the founders of Zero Carbon Food, the company setting up London's underground farm. Down in the curved tunnels of the Clapham North deep-level shelter, there will be room for only three stacks of plants. But the damp tunnels have been disused for many years so its owner, the local transport authority

DAVE STOCK

The light plants love is a strange mix of red and blue, seen here at London's underground farm

Transport for London, is leasing it on favourable terms. And the infamous vagaries of the UK's weather don't matter down there. "We can schedule stuff to the minute," farm manager Gabriel De Franco told me as he showed me around a small trial area late last year (pictured left).

But what about taste? Differences in the spectrum of the light they are grown under can certainly affect plants, and one batch of mustard microgreens I sampled tasted distinctly different from another batch grown under a different type of LED. There is concern about whether the lack of ultraviolet light makes plants grown indoors less nutritious, says Bugbee. But judging from my unscientific sample, they are no less delicious.

Rather, the main problem with growing indoors is the cost of the lighting, says Bugbee, who has worked with NASA and with several companies interested in growing plants entirely under electric light. You have to get a good price for your produce to cover the electricity bills – one reason why, despite a number of attempts starting in the 1980s, the only large-scale uptake of indoor farming has been among cannabis growers.

Fans of indoor farming, however, claim that advances in LEDs are now making indoor farming more than just a way of growing expensive plants. Some have even suggested that this is the future of farming and could help solve the world's food crisis.

Use your loaf

But for Bugbee, nothing fundamental has changed. "It is possible to operate a business growing specialty crops indoors sold to specialty markets," he says. "But the idea of growing our staple crops in vertical farms is ridiculous." Louis Albright of Cornell University in Ithaca, New York, has calculated that growing enough wheat under electric light to make a loaf of bread would run up a $23 electricity bill.

Mitchell is more optimistic about the prospects for indoor farming, but agrees that it isn't a viable way of growing staple crops on a large scale. "We are not going to be producing wheat, rice, corn and things like that in warehouses," he says.

That doesn't mean it couldn't be a financially viable way to grow high-value produce. But is it also, as many of the new enterprises claim, a greener way? The Zero Carbon Food website, for instance, states that the food it grows will have a "Reduced carbon footprint" and a "Lower energy consumption than glasshouse growing". The Green Sense Farms website says that "Growing near our customers means fewer food miles travelled, less fuel usage and significantly-reduced carbon emissions."

Growing food locally does greatly reduce food miles, but that doesn't necessarily mean lower overall carbon emissions. That's because transport-associated emissions are typically only a small proportion of the total emissions associated with producing food. In 2008, Albright produced a report for the New York State Energy Research and Development Authority on the emissions associated with food imported into the state compared with the same food grown locally. Most of the state's fresh produce comes from California or Arizona, and is transported almost 5000 kilometres on average. For lettuce, he has calculated that about 0.7 kilograms of carbon dioxide is produced per kilogram imported into the state. But lettuce grown locally in heated greenhouses with supplemental lighting was typically even more carbon-intensive – at up to 2.4 kg of CO_2 per kilogram.

The same applies in the UK. Kevin Frediani of Bicton College near Budleigh Salterton in Devon has tested one vertical farming system and, although he is a proponent of urban farming, points to studies showing that ›

ESTIMATED CO_2 EMISSIONS FOR 1 KG OF LETTUCE SOLD IN NEW YORK STATE

IMPORTED 5000 KM ON AVERAGE BY ROAD, RAIL AND AIR

0.7 kg

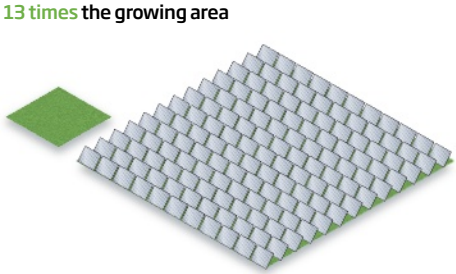
GROWN LOCALLY IN HEATED GREENHOUSES WITH SUPPLEMENTAL LIGHTING

1.2-2.4 kg

GROWN WITH LIGHT FROM THE CURRENT US ELECTRICITY GRID

8 kg

Running grow lights for indoor farming with solar power would require an area of solar panels 13 times the growing area



"The fundamental problem is that converting fossil fuels, wind or sunlight to electricity and then to light is very inefficient"

lettuce imported from Spain typically has a lower carbon footprint than lettuce grown in the UK during winter using current methods.

Albright, now retired, has calculated the CO_2 footprint of food grown entirely with light powered by electricity from the US grid – and his figure is a whopping 8 kg of CO_2 per kg of lettuce. "One hundred per cent light is an awful lot of carbon dioxide," he says. The fundamental problem is that converting fossil fuels, wind or sunlight into electricity, and then into light, is very inefficient – more than 90 per cent of the energy is lost along the way.

A common criticism of Albright's figures is that they are outdated and don't take into account the rapid advances in technology. But Bugbee, who published a study on the efficiency of grow lights just last year, says they are still valid.

Both Dring and Robert Colangelo, head of Green Sense Farms, question the conclusions. "It's very hard to compare field farming to greenhouses to indoor farming," says Colangelo. "I think the data is very nascent, the industry is very new. We have to be very careful in making an analysis."

Neither company could as yet provide figures showing that indoor farming produces fewer greenhouse gas emissions overall than conventional field or greenhouse growing. Dring points out that microgreens have a much shorter growing time and higher yields than lettuces. Microgreens do require less energy than other crops, Mitchell agrees, as they get some of the energy they need from their seed.

TOP: ARI BURLING/ GOTHAM GREENS; BOTTOM: IMAGE SOURCE/GETTY

Transport typically accounts for only a tiny proportion of the carbon emissions of supplying food

No free lunch

Zero Carbon Food will also be buying its electricity from a renewable electricity supplier. Using renewable energy to power the lights would certainly reduce carbon emissions compared with using grid electricity. But Bugbee thinks large-scale indoor food production would still have significant environmental impacts even if all the energy came from, say, solar power.

With LED and solar-panel efficiencies as they are, running grow lights entirely with solar power would require an area of solar panels 13 times the size of the growing area, he calculates. Manufacturing the massive arrays of solar panels required is a highly energy hungry process, and then there would be the problem of where to put them without covering over farmland or wildlife habitat.

"It's hard to replace free sunlight," Bugbee says. And if we are to limit dangerous climate change, we need both to reduce overall energy use and use every renewable energy source we create to replace fossil fuels. Growing food in more energy-intensive ways won't help.

Nevertheless, Mitchell thinks what he calls "controlled environment agriculture" – encompassing everything from conventional greenhouses to indoor farming – is set to grow. Lower energy costs because of fracking have made practices such as using supplementary light more affordable in the US, he says.

This doesn't have to be bad news for the climate, though. Albright and Frediani both think the carbon footprint of food grown in climate-controlled greenhouses can be greatly reduced by, for example, better insulation and smarter control systems, making local food grown in or around cities the clear green choice. A number of innovative approaches are being tested, Frediani says. "This has to be the way to go." ■

Michael Le Page is a features editor at *New Scientist*.
Links to the studies cited are available in the online version of the article at bit.ly/SunlessFarms

The materials bonanza

We're using more of more sorts of stuff than ever before. But what does that mean for us and the planet, asks ***Andy Ridgway***

YOU may have read about it here. You may have read about it elsewhere. Five or so years ago, the world was on the brink of crisis, one involving a group of chemical elements known as the rare earths. With exotic names such as yttrium, europium and dysprosium, they had become essential components of our fridges, televisions and smartphones – pretty much all electrical gadgets, in fact. But China, with a near monopoly on rare earth production, was slashing exports. Demand was about to massively outstrip supply.

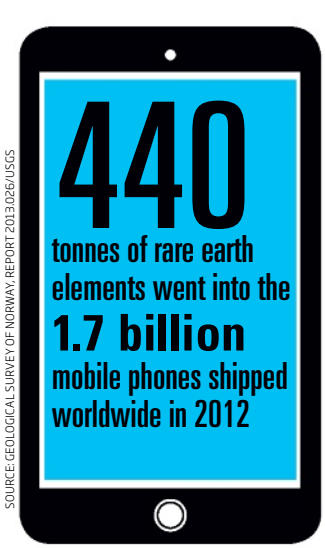
In the end, it was a bit of a damp squib. The price of some rare earth elements did soar to a peak in 2011 – and then dropped away again almost as fast.

How this storm brewed, but never broke, is an instructive story about our use of Earth's mineral resources today, and what that means for the future. Not so long ago we relied on just a dozen or so elements to make most of what we manufacture, ones with familiar names like iron, aluminium, copper and silicon, that are widely present in substantial quantities in Earth's crust. Now, though, our ambitions extend throughout the periodic table. Like Michelin-starred chefs, we are combining this material menu in increasingly exotic ways. That gives us a new flexibility, but makes us dependent on some obscure elements found only in small amounts and in a few places.

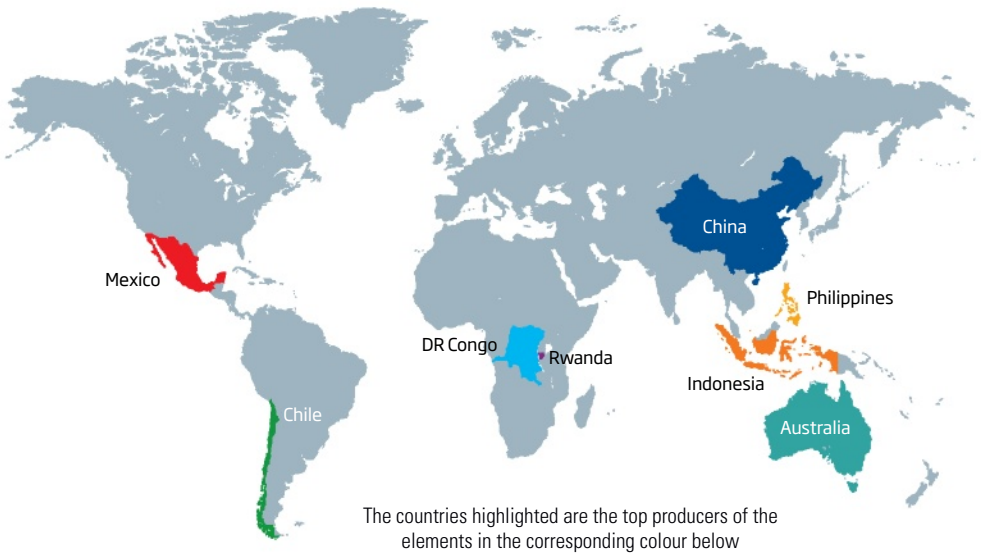
In this new material landscape, it's no longer just about how much stuff there is, but how much it costs, how we use it, where it is and who controls it. Over the next six pages, we take a look at how we are using Earth's mineral resources today – and what crunches we might anticipate in the future. ›

A WORLD IN YOUR SMARTPHONE

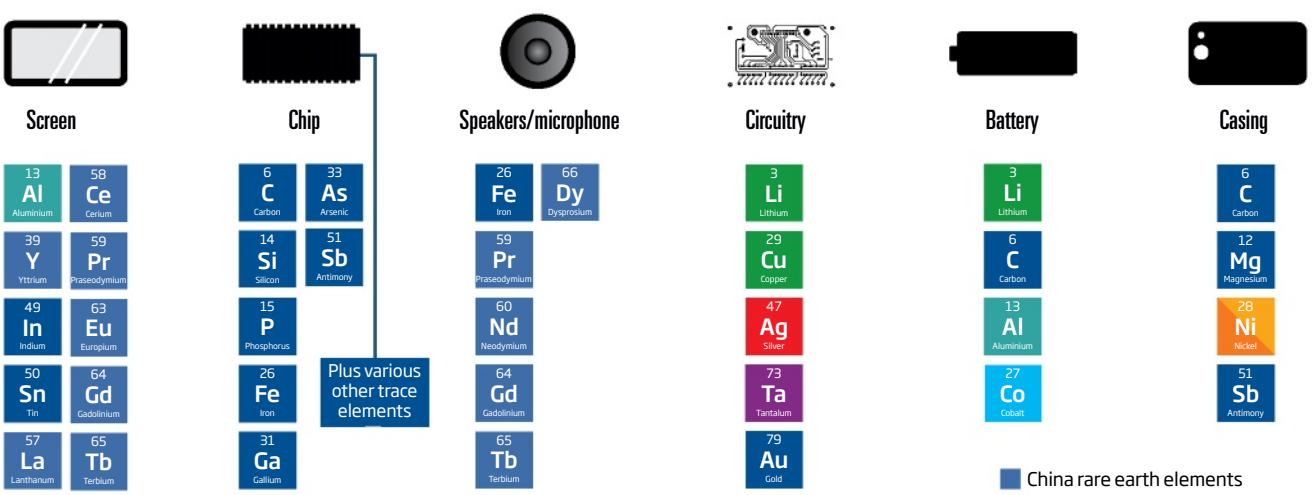
A typical smartphone contains dozens of mined elements sourced from all over the planet



SOURCE: GEOLOGICAL SURVEY OF NORWAY, REPORT 2013.026/USGS



The countries highlighted are the top producers of the elements in the corresponding colour below



If you are one of the estimated 2 billion people in the world that now own a smartphone, you are walking around with a periodic table in your pocket. Besides silicon in its chips, copper in the wiring and hydrocarbon-based plastics in the casing, there is indium and tin in the touchscreen, probably lithium and cobalt in the battery, and possibly antimony as a fire retardant in the outer shell. That's just the start: each smartphone contains at least 30 different elements, most probably more (see "A world in your smartphone", above).

The rare earth elements, a group of 17 that nestle towards the bottom of the periodic table, are also there in numbers. Yttrium, lanthanum, cerium, praseodymium, europium, gadolinium and terbium are exploited for their light-emitting properties to make the colours of the screen. Tiny but powerful magnets in the microphone, speaker and motion sensor contain crucial doses of neodymium, dysprosium and others.

It's not just smartphones. Europium gives colour to liquid crystal televisions and low-energy light bulbs, and makes euro banknotes glow under ultraviolet light as an anti-forgery measure. Magnets containing neodymium and dysprosium power the wind turbines and electric cars of the green energy revolution.

In the decade or so before China put on the brakes in 2010, global production of rare earths had more than doubled (see "The rare earth story", above right). When China announced a 40 per cent cut in its export quota, it controlled 97 per cent of the world's rare-earth supply. At its peak in July 2011, the price of a 1-kilogram lump of dysprosium had skyrocketed to over $3000, 20 times the price just two years before.

But rare earth elements aren't actually rare. Although they aren't nearly as abundant in Earth's crust as something like aluminium or iron, they are all present in parts per million, with workable deposits dotted across the planet. China just happened to mine them more cheaply. In fact, a mine at Mountain Pass in the Mojave desert, California, had been the world's leading producer of rare earths before it closed in 2002 in the face of Chinese competition and local environmental concerns.

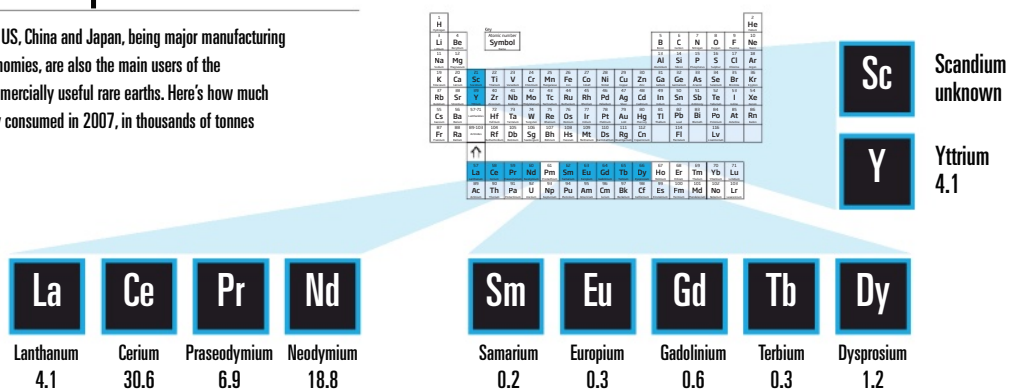
One effect of the Chinese cut in exports was to rewrite that equation. By August 2012, mining company Molycorp had restarted

THE RARE EARTH STORY

Our consumption of rare earth elements is growing as they are used in more and more devices and processes. China dominates the market and its restriction on exports caused a price spike in 2011

Consumption

The US, China and Japan, being major manufacturing economies, are also the main users of the commercially useful rare earths. Here's how much they consumed in 2007, in thousands of tonnes

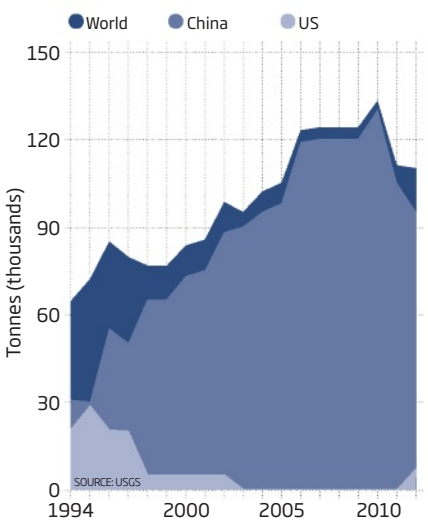


Risk rating

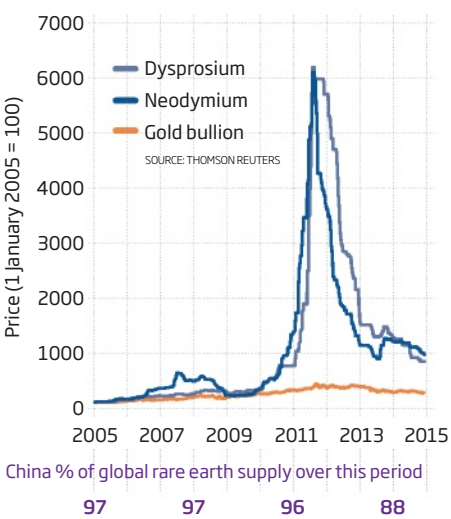
9.5

Risk (out of 10) of the supply of these elements being interrupted, as calculated by the British Geological Survey

Production



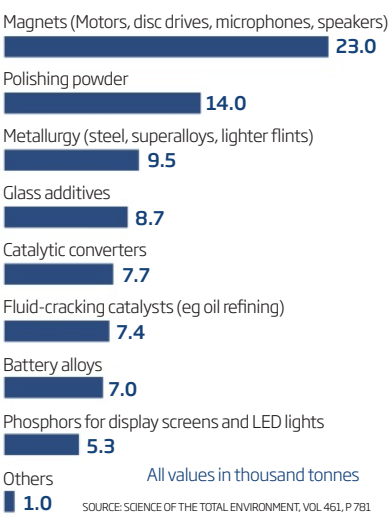
Price



China % of global rare earth supply over this period

97	97	96	88

Applications



production at Mountain Pass. In November 2012, a mine at Mount Weld in Western Australia also opened its doors. Starting a new mining operation is a notoriously slow business, but this time companies had seen the crisis coming. "Something that looks like a strategic vulnerability to people in government looks like a business opportunity to entrepreneurs," says Eugene Gholz, an economist at the University of Texas at Austin and a former Pentagon adviser. "If there is restricted supply, entrepreneurs expect prices to go up, so they start to invest." According to Gholz, there are now more than 200 mining firms worldwide trying to convince investors to put money into new rare earth deposits.

Meanwhile, companies making products containing rare earths also took matters into their own hands, reducing their use of them or stopping it entirely. "The price spike caused demand destruction for many rare earths, as a lot of manufacturers designed them out of their products," says David Merriman, an analyst at mineral consulting firm Roskill Information Services in London.

So what does this rare earth non-crisis tell us? First, that in absolute terms we aren't in danger of running out of any material resource just yet. Despite a sharp uptick in our use of most elements in the past decade or so – and that in the teeth of a major recession – our consumption represents at most a few per cent of known reserves. That goes for the rare earths and other less common elements, but also for the traditional elements we still use the most: iron, aluminium, copper and zinc. And reserves are just the amount of stuff considered economic to mine at any one time. As one reserve is exhausted or becomes too expensive, so others may open up, as China found out. By last year, its share of the global rare-earth market had fallen to 88 per cent, and it is expected to sink to 75 per cent in the next few years.

So there's nothing to worry about. There's plenty of stuff to go round, and market forces, plus our new capability to mix and match many elements, mean we needn't fear supply crunches: we will innovate past them. "The main message is don't panic, people are ingenious and will find a way around problems," says Gholz. In a working paper for the US Council on Foreign Relations published last October, he argues ›

HIGH RISK

Supplies of several non-rare-earth elements used in small but crucial quantities are deemed insecure

74 W TUNGSTEN

Risk rating **9.5**

Production: 71 ktonnes ↑ 18%
Reserves: 3.5 Mtonnes

Major producers: China 85%, Others 15%

Major reserve holders: China 54%, Others 46%

Where you might find it: Halogen lamps, drill bits

51 Sb ANTIMONY

Risk rating **9**

Production: 163 ktonnes ↑ 15%
Reserves: 1.8 Mtonnes

Major producers: China 80%

Major reserve holders: China 53%, Russia 19%, Bolivia 17%

Where you might find it: Toys (flame retardant), clothes

83 Bi BISMUTH

Risk rating **9**

Production: 7.6 ktonnes ↑ 100%
Reserves: 0.3 Mtonnes

Major producers: China 86%

Major reserve holders: China 75%

Where you might find it: Stomach medicine, pigment in make-up

42 Mo MOLYBDENUM

Risk rating **8.6**

Production: 270 ktonnes ↑ 113%
Reserves: 11 Mtonnes

Major producers: China 41%, USA 23%, Chile 14%

Major reserve holders: China 39%, US 25%, Chile 21%

Where you might find it: Spark plugs, aircraft engines

41 Nb NIOBIUM

Risk rating **7.6**

Production: 51 ktonnes ↑ Unknown
Reserves: 4.3 Mtonnes

Major producers: Brazil 88%

Major reserve holders: Brazil 95%

Where you might find it: Jet engine alloys

Pt *Platinum group metals

Risk rating **7.6**

Production: 0.4 ktonnes ↑ 12%
Reserves: 66 Mtonnes

Major producers: South Africa 50%, Russia 27%

Major reserve holders: South Africa 95%

Where you might find it: Catalytic converters

27 Co COBALT

Risk rating **7.6**

Production: 120 ktonnes ↑ 155%
Reserves: 7.2 Mtonnes

Major producers: DR Congo 48%

Major reserve holders: DR Congo 47%, Australia 14%

Where you might find it: Turbines, magnets, batteries

49 In INDIUM

Risk rating **7.6**

Production: 0.77 ktonnes ↑ 161%
Reserves: Unknown

Major producers: China 53%, S Korea 19%

Major reserve holders: By-product of zinc mining

Where you might find it: Touchscreens

that China is unlikely ever to regain its grip on rare earth supplies.

But it might not all be that straightforward. One question is how much of Earth's mineral resources it is sensible or desirable to extract. It's a question more often posed of our burning of hydrocarbons, which contributes more directly to dangerous warming of the planet, but the mining and refining of all metals are energy-intensive businesses.

"Can the planet cope with us extracting more and more of these things, burning more and more carbon to get them out and using more and more water? In certain parts of the world that's becoming a real issue," says Andrew Bloodworth of the British Geological Survey (BGS) in Keyworth, near Nottingham.

Perhaps surprisingly, life-cycle analyses of the environmental impact of mined elements, taking into account energy consumption and toxicity to human and other life, are comparatively thin on the ground. One of the most comprehensive was undertaken last year by Philip Nuss of Yale University and Matthew Eckelman of Northeastern University in Boston, Massachusetts. They showed that many "speciality" elements we are now using more of, such as the rare earths, do greater environmental damage on a per-weight basis than more traditional materials (see periodic tables of energy demand and toxicity, page 40). The worst offenders are the group of precious metals centred around platinum, including iridium and osmium, as well as palladium, rhodium and ruthenium, which are used in catalytic converters and as catalysts to make pharmaceuticals and fertilisers and in oil refining. Nevertheless, the comparatively small amounts of these elements in circulation means the list of the greatest environmental sinners overall has a familiar ring: iron, aluminium, calcium, copper and mercury (*PLoS One*, vol 9, p e101298).

But even discounting environmental concerns, there are other clouds on the horizon. In the case of the rare earth non-crisis, we were lucky that there happened to be mothballed capacity elsewhere when a supply crunch came. Rapid action reduced prices – and is continuing to do so to such an extent that the mining companies that stepped into the breach are now finding it difficult to turn a profit or attract investment. The activities of speculators on commodities markets, as well as the panic buying of rare earths in the aftermath of the Chinese announcement, also increased volatility. "Market speculation has

LOW RISK

Supplies of the most heavily used elements seem relatively assured

6 C CARBON (GRAPHITE) — Risk rating **8.1**

Production	1200 ktonnes	50%
Reserves	130 Mtonnes	
Major reserve holders		
Major producers		
Where you might find it	Pencils, batteries, brakes	

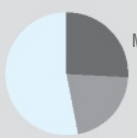
32 Ge GERMANIUM — Risk rating **8.1**

Production	0.16 ktonnes	252%
Reserves	Unknown	
Major producers		
Major reserve holders	By-product of zinc mining	
Where you might find it	Camera lenses, DVDs	

26 Fe IRON — Risk rating **5.2**

Production	3000 Mtonnes	264%
Reserves	170 Gtonnes	
Major producers		
Major reserve holders		
Where you might find it	Steel	

13 Al ALUMINIUM — Risk rating **4.8**

Production	259 Mtonnes	80%
Reserves	28 Gtonnes (bauxite)	
Major producers		
Major reserve holders		
Where you might find it	Drinks cans, car bodies	

31 Ga GALLIUM — Risk rating **7.6**

Production	0.27 ktonnes	327%
Reserves	Unknown	
Major producers	Figures not available	
Major reserve holders	By-product of aluminium mining	
Where you might find it	Blu-ray players, mobile phones	

Production and reserve figures are for 2013

▲ % production increase from 2003 to 2013

Risk ratings are calculated by the British Geological Survey on the basis of amount and concentration of known reserves, substitutability and recyclability of the resource, and good governance in producing and reserve-holding countries.

Other elements with high risk ratings

Strontium	8.6	Thorium	7.6
Mercury	8.6	Arsenic	7.6
Barium	8.1	Magnesium	7.1
Beryllium	8.1	Tantalum	7.1

30 Zn ZINC — Risk rating **4.8**

Production	13.5 Mtonnes	59%
Reserves	250 Mtonnes	
Major producers		
Major reserve holders		
Where you might find it	Galvanised steel	

29 Cu COPPER — Risk rating **4.2**

Production	17.9 Mtonnes	29%
Reserves	690 Mtonnes	
Major producers		
Major reserve holders		
Where you might find it	Wiring	

USGS

played a very important role in rare earth prices, which in turn has affected supply and demand," says Merriman.

Meanwhile, China still supplies 97 per cent of "heavy" rare earths, such as terbium and dysprosium, which aren't produced commercially at Mountain Pass or Mount Weld. "The industry has hardly moved on from the situation we had before – China still produces the vast majority of rare earths," says Merriman. This might just be a crisis delayed.

It isn't all about the rare earths, either. Certainly they stand at the top of most experts' lists of "critical" materials for which we cannot rely on future supplies. Drawing up such lists is fraught with difficulty, not least because it is difficult to predict how our use of technology will change. Demand for electric cars, bikes and buses hasn't risen as much as forecast, for instance, says Frank Marscheider-Weidemann of the Fraunhofer Institute for Systems and Innovation Research in Karlsruhe, Germany. That has lessened pressure on neodymium and dysprosium supplies, and possibly kept demand for platinum-group metals for catalytic converters higher.

Something similar applies for compact fluorescent light bulbs, and hence demand for some rare earths such as yttrium; LED lights, which need much less of the rare earths, have proved more popular. On the other hand, demand for wind turbines and photovoltaic cells is buoyant, adding pressure on neodymium and dysprosium in the case of turbines, and elements such as silver, gallium and indium in the case of photovoltaics.

Despite such uncertainties, we can pick out some consistent risk factors. Concentration of reserves or production in only a few places is one: the rare earths, tungsten, antimony and carbon in the form of graphite in China, or the platinum group of metals in Russia and South Africa. Some 85 per cent of the world's supply of niobium, an element used to make high-strength steel alloys, currently comes from just one mine in Brazil, says Bloodworth.

Just as with the rare earths, it is not always that other countries don't have reserves. "China dominates production of many metals not because they have any more tungsten than anyone else," says Bloodworth. "But they have the smelters and the big kit, and the West has lost interest in doing a lot of these things. We've exported our heavy industry and environmental obligations somewhere else."

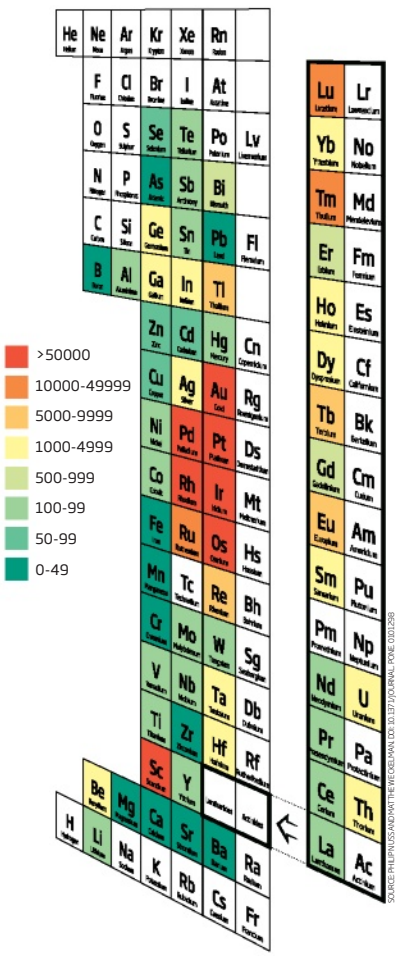
Another risk is when in-demand elements are by-products of mining for something ›

THE TABLES

Many different factors – environmental, economic and political – make reliance on mined elements more or less desirable

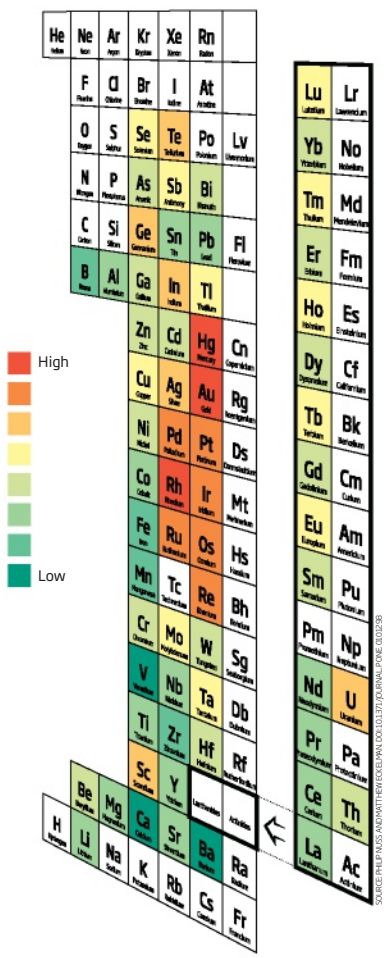
Energy

Energy to mine and process 1 kilogram, in megajoules



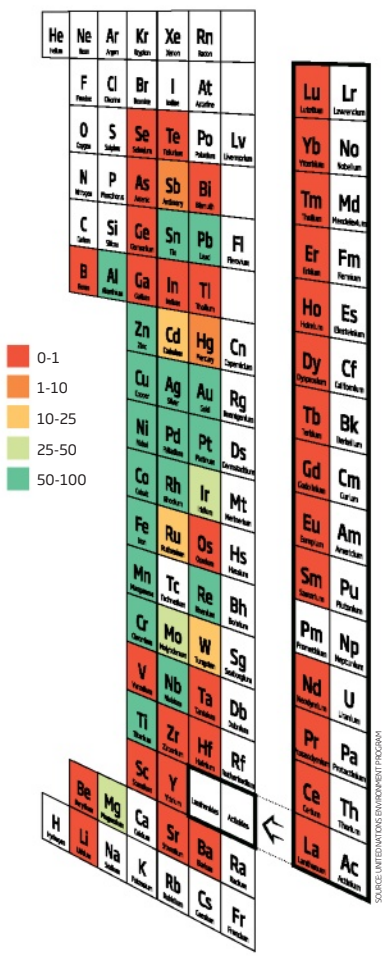
Toxicity

Toxicity to humans



Recycling

Recycling rate (%)



else. One example is gallium, used as a semiconductor in the likes of smartphones and for Blu-ray lasers. It is present in bauxite ore, the main source of aluminium, in concentrations of between 10 and 180 parts per million. Gallium is one of the fastest-growing of the new breed of elements: the European Commission predicts consumption in the European Union will increase by 8 per cent every year until 2020.

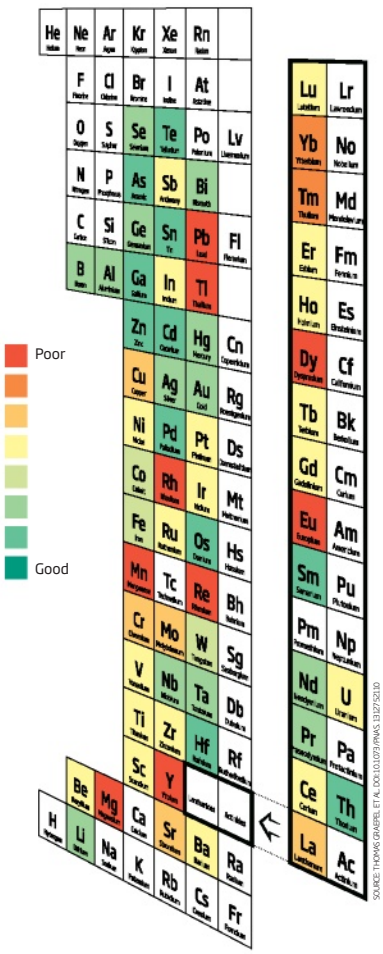
At the moment, demand for fresh aluminium is sufficient to cover our gallium needs and then some, says Daniel Beat Mueller of the Norwegian University of Science and Technology in Trondheim. But as more and more aluminium is recycled, bauxite production is set to decline – and with it gallium supplies. "The amount of gallium that's used and its price would never justify mines for gallium alone," says Mueller. It is a similar, less acute story for tellurium, a copper by-product used in solar cells, and hafnium, a companion to titanium used in small amounts in many applications, from nuclear fuel rods to integrated circuits.

Recyclability is also a factor that affects an element's riskiness. Again, it's not the traditional elements, which tend to be used in bulk, that are the problem: it is relatively easy and cheap to recycle iron from a lump of steel or aluminium from a drinks can. According to the United Nations Environment Programme (UNEP), recycling rates for these elements, as well as for copper, zinc, tin and lead, are above 50 per cent. But flatscreen televisions, smartphones and batteries, often thrown away after just a few years or even months of use, are locking up an increasing amount of the newly essential elements. A UNEP report published in 2011 identified 34 metals with recycling rates of less than 1 per cent, including all the rare earths, gallium, indium, hafnium, tellurium and a host of other speciality metals (see periodic table, above).

You might say that were the prices of these elements to rise, it would increase the incentive to recover more of them. But there are constraints to this, not least because of the increasingly complex blends of metals we use to make products. "There are thermodynamic limits to how much can be recovered from the waste stream," says Nuss. "Some metals mixed with other elements can't simply be recovered and then used with their original functionality." Without more focus on designing electronic products from which

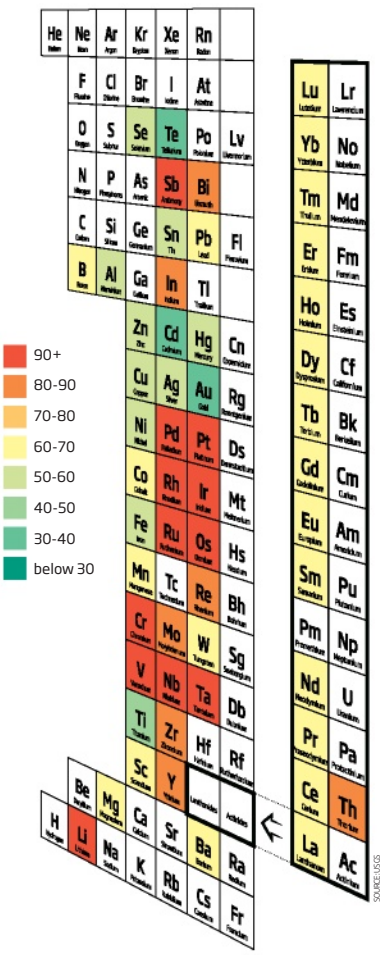
Substitutability

Ease of replacing in end applications by another element



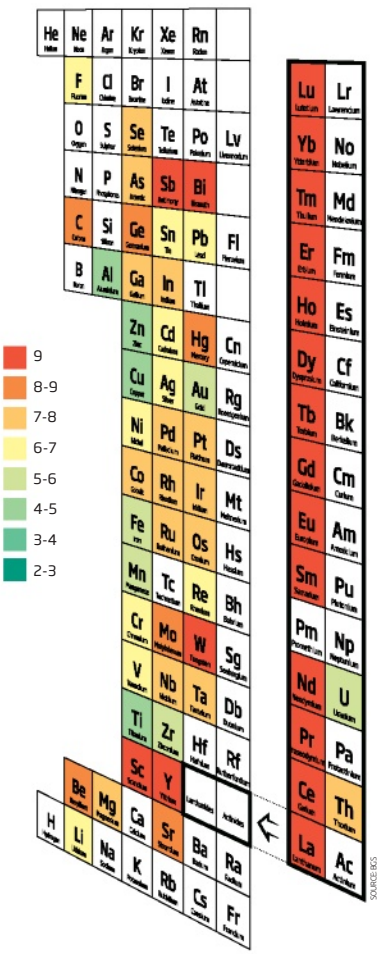
Distribution

% of total resource in top three reserve-holding countries



Risk rating

According to the British Geological Survey (see text)



individual elements can be easily recycled, that is likely to remain a problem.

This is a particular concern when an element has low "substitutability" – that is, we know of no other element that can do the same job. According to a study by Thomas Graedel and his colleagues at Yale University, some familiar names such as magnesium and lead fall into this category. With relatively abundant supplies of these elements, this is less of a concern. For europium and dysprosium, on the other hand, it is a big worry.

Risk factors can play off against each other. Some platinum-group elements have low substitutability, for example, but "the good news is that we're really good at recycling them", says Bloodworth. His colleague at the BGS, Richard Shaw, has compiled a risk list that pulls together many of these factors – amount and concentration of known reserves, substitutability, recyclability and good governance in producing and reserve-holding countries – to give a sense of which elements we would do well to rely on less. "We wanted to come up with something in which people could see our working," says Bloodworth. "We used publicly available sources of information and a pretty simple algorithm to calculate what the end result is."

The riskiest elements at the top of the BGS ranking are metals used on small scales in niche applications with few sources: the rare earths, tungsten and antimony. At the bottom are elements such as aluminium, zinc and copper, where a geographical spread of resources and high recycling rates mean we can reasonably expect continuity of supply (see element risk profiles on pages 38 and 39).

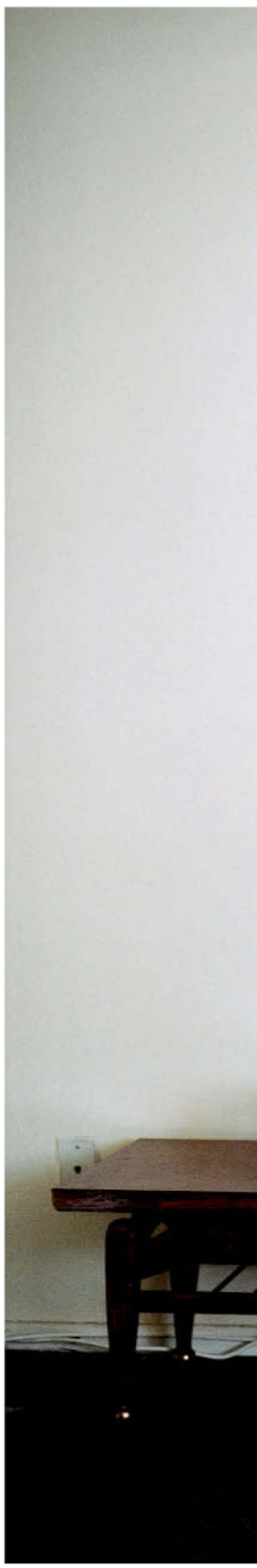
In May last year, an EU-wide exercise came to similar conclusions, anointing a series of "critical materials", among them antimony, gallium, germanium, graphite, magnesium, indium, niobium and tungsten, as well as the rare earths and platinum-group metals.

The diagrams on these pages give more insight into some of the complexities of this new material world we have created. Perhaps, as with the rare earth crisis that wasn't, we will deftly continue to sidestep impending crunches. But with a whirl of geopolitical, economic and environmental factors in play – and a whole periodic table now to keep tabs on – the most certain thing about our material future is uncertainty itself. ■

Andy Ridgway is a freelance writer based in Bristol, UK. Additional data reporting by Richard Webb

Snog, marry, avoid?

Forget the stereotypes. What we really, really want in a partner is pretty complicated, finds **Mairi Macleod**



WHEN it comes to romantic liaisons, evolution has honed our preferences. Just as a peacock impresses with his feathers, so heterosexual humans look for the telltale signs of a good mate that will boost their reproductive fitness. Women want masculine, dominant men – protectors and providers, with high testosterone levels and good genes that can be passed on to offspring. Men go for physically feminine women, whose hourglass figures signal top-notch fertility. At least, that's what we are often told. If you've always thought it sounded a bit simplistic, you were right. Increasingly, research is revealing that the rules of attraction are far more nuanced. Our preferences are personal and flexible, shaped by factors such as our environment, social status and economic prospects. It's time to question the stereotypes and rewrite the rulebook.

WOMEN FIND WEALTH AND STATUS ALLURING

When asked to rate the importance of qualities in a partner, men rank attractiveness more highly than women do, and women rank wealth and ambition more highly than men do. But what people say they want and what they actually choose do not necessarily match up. Paul Eastwick and Eli Finkel at the University of Texas, Austin, discovered that although participants in a speed-dating event showed the expected gender differences beforehand, once they sat down with potential partners both sexes placed most importance on physical attractiveness, followed by personality and then earning prospects.

What men and women prioritise often depends on the type of relationship they are looking for, says Steve Stewart-Williams at Swansea University, UK. "For one-night stands and other short-term relationships, women usually put a lot of weight on how good-looking the guy is – often more than men." A woman's own earning potential also plays a part. In an online survey of over 4000 women, Fhionna Moore of the University of Dundee, UK, found that women who were in control of their financial affairs were more interested in a partner's physical attractiveness than the size of his bank balance. Separately, Nicola Koyama at Liverpool John Moores University, UK, found that the more feminist a woman's attitudes were, the less importance she placed on a partner's earnings, and the more she liked men who were "kind and understanding" and "creative". "[Western] women are likely to have different mate preferences compared with previous generations," she says.

MEN PREFER AIRHEADS

Marilyn Monroe was an intelligent woman, but you wouldn't have guessed it seeing her perform "Happy Birthday Mr President" at Madison Square Garden in 1962. She's not the first female to play down her smarts to appeal to a man. Which is odd, because most men actually prefer intelligent women, at least as long-term partners. What gives?

Cari Goetz of California State University in San Bernardino believes the allure of stupidity lies in the perception that intellectually challenged women are sexually available. Her team found that men were attracted to images of women who looked immature, intoxicated, reckless, promiscuous, eager for attention, unintelligent and young. "All of these were correlated with being perceived as sexually exploitable and sexually attractive," she says. Her research also suggests that women could conceivably play on this when they want sex rather than a committed relationship. But a ›

OLIVIER CULMANN / TENDANCE FLOUE

PAUL FUSCO/MAGNUM PHOTOS

House husbands: sexier now than they were a generation ago

"Women who are grossed out by blood and faeces prefer more masculine faces"

follow-up study found wide variation among men, with those lacking empathy and wanting uncommitted relationships being most likely to fancy dumb women. Even they moderated their behaviour when in a relationship.

WOMEN GO FOR MACHO MEN

There is plenty of evidence that men with more masculine faces, voices and even body odour are more attractive to women – when they are ovulating. Most of the time, however, most women, in Western societies at least, favour distinctly feminine, Ryan Gosling types. The thing is, masculinity in men is associated with marital strife and infidelity, but also with good genes. So it makes sense that a macho hunk should be most attractive to a woman when she can get pregnant.

For most of women's lives, though, that's not the case – which might help explain why prepubescent girls and post-menopausal women prefer more feminine-looking men. The same goes for new mothers, focused on maternal care. "Women experience a substantial drop in their oestrogen and testosterone levels post-partum," says Kelly Cobey of the University of Stirling, UK. These hormones are thought to affect the way women judge attractiveness.

Another line of research hints that any preferences for macho men may be diminishing as the world becomes more sanitary. Lisa DeBruine at the University of Glasgow, UK, and her colleagues found that women who are most sensitive to signs of disease, "those who were more grossed out by things like touching a bloody cut or stepping in dog poo", tend to prefer more masculine faces. What's more, women who live in parts of the world where disease risk is high are more attracted to masculine facial features than are women living in healthier places. DeBruine thinks that good genes are especially important where a strong immune system is needed for healthy offspring.

But even where disease is rife, macho men aren't necessarily preferred. When Carlota Batres of St Andrews University, UK, compared women in El Salvador with and without internet access, she found the latter preferred more feminine-looking men. Many factors might account for this, but Batres suspects that poverty is influencing their tastes. Previous research reveals that women primed to think about resource scarcity prefer good-dad, "nurturing" traits, which are associated with more feminine-looking men, she says.

WOMEN CHOOSE MEN WHO RESEMBLE THEIR FATHER

There is some truth in this. A team led by Tony Little of the University of Stirling, UK, found that women's partners often have the same hair and eye colour as their dads. What's more, women also tend to prefer older men if their own fathers were relatively old when they were born, and men whose face shape matches their father's – particularly if they had a good relationship with their dad. The thing to realise is that being more genetically similar to your partner isn't necessarily a bad thing. For a start, your offspring have a better chance of inheriting groups of genes that work well together if you and your partner have these genes in common. And there's another potential genetic benefit. "Shared genetics between partners can lead to offspring that are more related to their parents than would happen if they mated at random," says Little. All this might help explain his finding that men's partners tend to have the same hair and eye colour as their opposite sex parent too.

TREAT THEM MEAN TO KEEP THEM KEEN

Acting cool sends the message that you have plenty of other options, so it makes sense that it might persuade someone to pursue you. But if you want a committed relationship, it's a bad idea, according to psychiatrist and writer, Amir Levine, because it is likely to attract someone who avoids attachment.

Psychologists have found that the more secure a child is in their emotional bond with a parent, the more they are able to go out into the world with confidence. Levine believes adults have attachment styles too, which influence their behaviour in relationships. Securely attached adults aren't afraid of commitment and are good at communication and compromise, so they don't feel the need to play games and tend to avoid people who do. Playing hard to get is likely to attract "avoidants" who value their independence and want to keep partners at arm's length.

DOMESTICATED MEN AREN'T SEXY

If you're a woman, does a man pushing a vacuum cleaner round turn you on? Do you fancy a bloke wearing an apron or kitchen gloves? A study published in 2013 suggests the answer is likely to be "no". It revealed that couples with more traditional divisions of labour in the home – where men did jobs like DIY and mowing the lawn – had more sex than those in which men did their share of the cooking and cleaning. Women in the less egalitarian partnerships also reported being more sexually satisfied.

However, the study was based on interviews carried out in the late 1980s and early 1990s, and things might be different today, with women bringing home an increasingly large slice of the bacon. If they want to have babies as well as put in the hours required in the boardroom, then they are going to need someone to help shoulder responsibilities on the home front. So Daniel Carlson at Georgia State University decided to take another look. When he and his colleagues analysed a 2006 survey, they found that couples who shared the housework had at least as much sex as those with more traditional roles. "In the 80s, egalitarian couples were at the forefront of change," he says. "Today's couples have those examples to look to. It makes it a lot easier, resulting in higher-quality relationships."

MEN PREFER AN HOURGLASS FIGURE

Feminine features such as big eyes, pert little noses, small chins and a curvy hourglass figure signal high levels of oestrogen and are linked to fertility and health. So, all else being equal, it makes sense for men to be especially attracted to the likes of Beyoncé and Kim Kardashian. However, all else is not equal.

Although many studies suggest a waist-to-hip ratio of 0.7 is most attractive, women with larger waists may have advantages in certain situations. Elizabeth Cashdan at the University of Utah in Salt Lake City points out that they have higher levels of testosterone and cortisol, which may help them outcompete their wasp-waisted counterparts when resources are scarce. Indeed, the waist circumference of *Playboy* models has risen during periods of recession, according to a study tracking socioeconomic changes from 1960 to 2000.

Similarly, when men in 28 countries were asked to rate pictures of women's faces that had been morphed to make them more feminine or masculine, those from less well-off countries had less of a preference for femininity. "Women who are highly feminine are perceived to be less dominant and less effective in competing for resources," says Urszula Marcinkowska at Jagiellonian University, Poland, who led the study. In addition, men who had to cope with high levels of pathogens during childhood are likely to have lower testosterone, a hormone linked with a preference for ultra-feminine women.

Right place, right time? Who we find most attractive is influenced by our environment

STUART FRANKLIN/MAGNUM PHOTOS

FIRST IMPRESSIONS ARE ALL-IMPORTANT

Eastwick asked 129 undergraduates to rate their opposite-sex classmates on a range of qualities, at the beginning of the first semester and again at the end. Initially there was a high degree of consensus on how attractive individuals were, reflecting research showing that people are pretty much in agreement about somebody's "mate value", or appeal as a partner. However, after just one term of getting to know each other, his students had increasingly divergent opinions about the attractiveness of their peers. Eastwick puts this down to a quality that affects our perception of attractiveness and that can only be assessed once we get to know another person's foibles: he calls it "uniqueness".

It's well known that partners tend to be matched in terms of physical attractiveness. However, Eastwick's latest research reveals that this is less true for those who got to know each other well before starting a relationship than for those who began dating soon after meeting. Here, unique appeal is likely to have made up for any attractiveness deficit, he says.

WOMEN WANT COMMITMENT

For men, promiscuity offers the possibility of having many babies. That is not the case for women, but they may benefit in all sorts of other ways, from getting better genes and more resources for their kids to improving their own social network and prospects. Whether or not women choose this approach depends to a large degree on the social consequences, which are linked to factors such as religion and economics.

NATHANIEL WELCH/REDUX/EYEVINE

They might seem less alluring when times are tough

A team led by Michael Price at Brunel University London found a correlation between female economic independence and acceptance of promiscuous behaviour – both male and female. "As the gender pay gap has decreased in the UK and other Western countries, and women have become more financially independent, the relative costs of engaging in promiscuity versus pair bonding have gone down, and so cultural rules against promiscuity have become more relaxed," he says. This could help explain the finding that women in the UK report having eight sexual partners on average over their lifetime – almost twice as many as a generation ago.

MEN WANT CASUAL SEX

When it comes to sociosexuality scores – a measure of a person's propensity to have sex without commitment – men trump women. But it's not that simple. There is huge overlap in the scores of the two sexes, and more variation within them than between them.

Promiscuity is just one mating strategy. Many men invest a lot in their offspring, which is good for the kids and so their own reproductive success. The costs and benefits of these different approaches will depend on the scarcity of women and also on a man's individual qualities. Durante thinks that we figure out our mate value at some period in adolescence, and it's then that many men realise promiscuity is not a great option for them. Even the most attractive males are likely to settle down at some point, notes Stewart-Williams. "These men – the most eligible bachelors, the highest-status males in our species – often do what male chimpanzees never do: they fall in love." ■

"As the gender pay gap decreases in the West, attitudes to promiscuity are relaxing"

Mairi Macleod lives in Edinburgh, UK. Links to research can be found in the online version of this article

A creative accounting

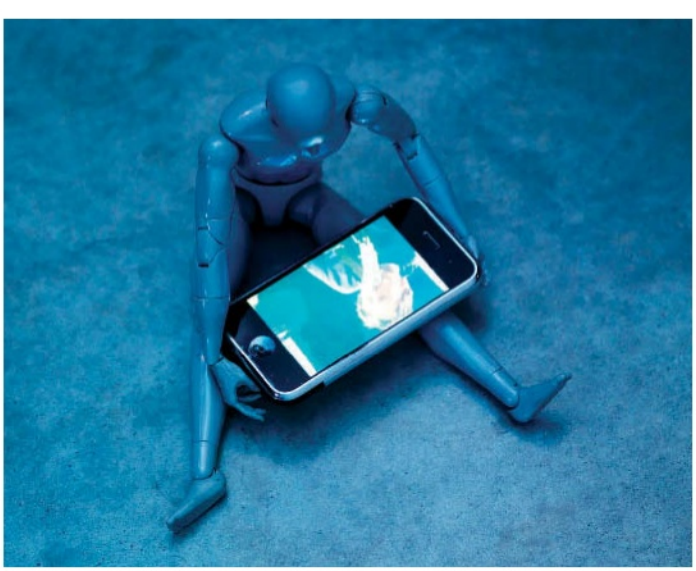
As automation gathers pace, the robochickens are finally coming home to roost, finds **Mike Holderness**

Rise of the Robots: Technology and the threat of a jobless future by Martin Ford, Basic Books, $28.99
Culture Crash: The killing of the creative class by Scott Timberg, Yale, $26.00
The Internet is Not the Answer by Andrew Keen, Atlantic Books, £16.99

WHAT you are about to read was written by a human. Honest. In draft, this article included an array of self-referential flourishes designed to convince you it was not the output of a machine intelligence, but they were taken out by the team of human editors who insisted it be clear and stick to a point.

This assurance may be more necessary than you suspect in an age in which automation has penetrated everywhere and even the creative classes fear for their livelihoods. Take *Rise of the Robots*, one of a trio of new books addressing the future of both work and the online trend for everything to be "free". Its author, software entrepreneur Martin Ford, asserts that websites such as Forbes.com are making more use than they admit of software like Quill, which generates news reports from raw data.

Whether or not this is yet true, it sharpens the question: what is to become of creative work? And why does it matter? This is the beef of *Culture Crash*, the second of our trio. Here, Scott Timberg, an arts reporter for the *Los Angeles Times* before the paper cut its culture coverage, explores the questions in engagingly written and thoroughly researched detail. Though just how much of his very wide reading was done online is, of course, a moot point.



How long before the robots ponder taking their own selfies?

EMMANUEL PIERROT / AGENCE VU/CAMERAPRESS

"When city halls or statehouses... don't get attention from trained, fair-minded observers," asks Timberg, "what appalling developments will we not hear about until it's too late? How will we learn about the next Watergate, the next Enron, if no one is paying attention?"

Could all this be the "creative destruction" declared as an engine

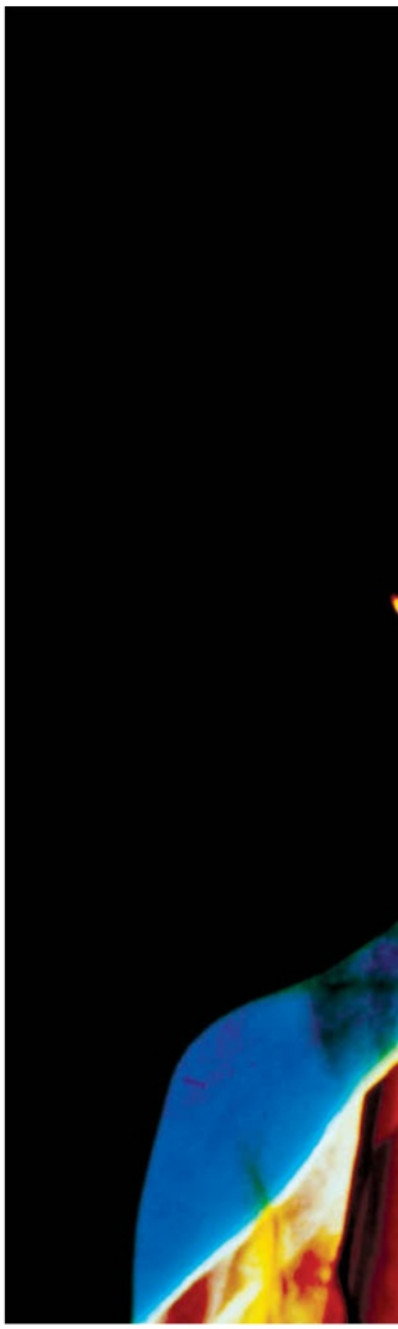
"Massively open online courses are an attempt to have a winner-takes-all economy of teaching"

of economic growth by the likes of economist Joseph Schumpeter? Or is the "winner-takes-all" economy – in which the dynamic of digital markets produces only one search engine, Google, and a few singers, say Taylor Swift and Lady Gaga – a deep threat?

Timberg thinks so. No field of creative endeavour is immune. Massively open online courses (MOOCs) are in fact a calculated attempt to have a winner-takes-all economy of teaching. If they ever work, every student will listen to the lectures of the best professor in the world; there will be no teaching income for the middle-ranking academic.

But the death of the "creative class", Timberg acknowledges, has other causes, most notably the disappearance of the cheap accommodation and, in some places, the malleable employment benefits that allowed the artists he reviewed room to experiment.

As a reviewer, Timberg would naturally argue that criticism and review are also essential to

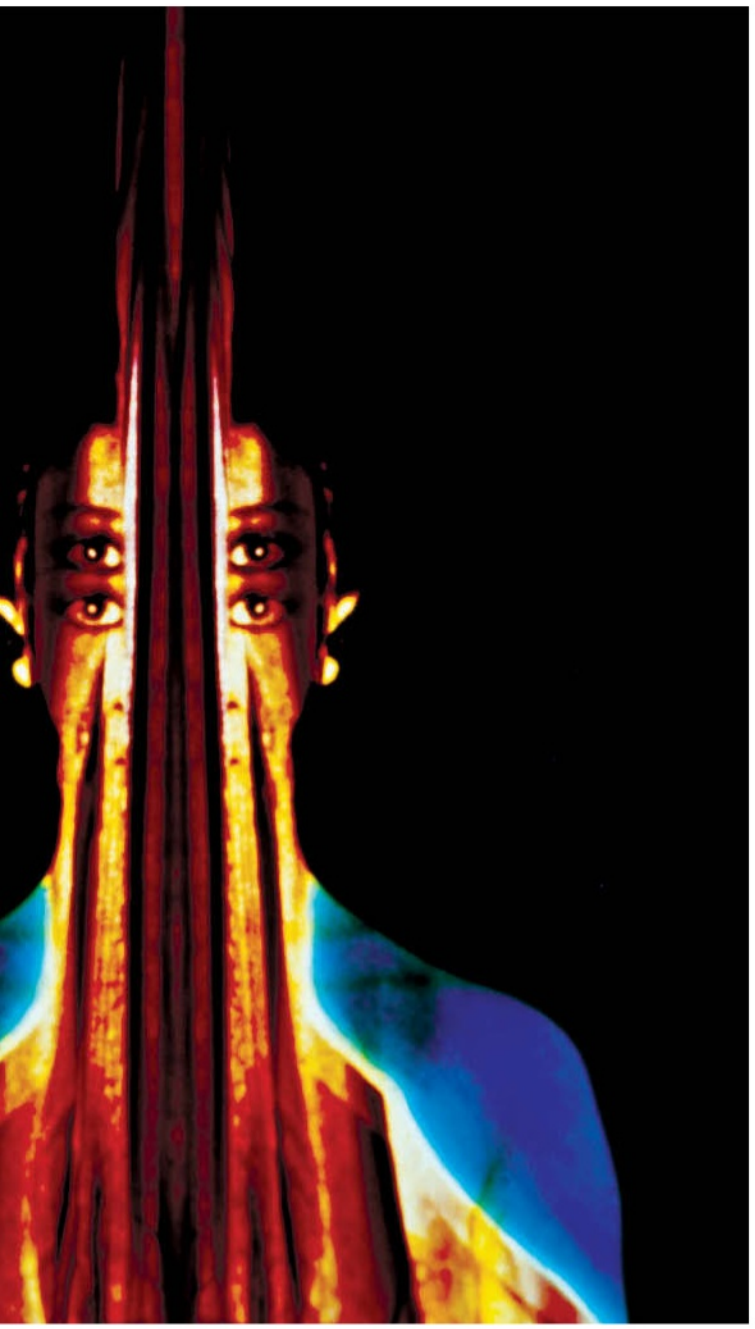


NARESH SINGH / MILLENNIUM IMAGES UK

You may also like... our preferences are being reflected back at us

a creative economy. He bemoans the unintended consequences of structuralist and post-structuralist scholars' efforts, mostly motivated by a democratic urge to open up the discourse to non-professional voices.

These consequences helped to



create a "critical school that did not want to distinguish between good and bad, better or worse, but to reflect people's preferences – and the marketing that shaped them – back to them". And that reflection is what we see in the nascent artificial intelligences of Google and Amazon when our purchasing habits trigger an unwelcome "you may also like… "

Timberg champions the need for a "middle class" of creators who can make a decent, but not spectacular, living from their work – from the work itself, not from T-shirts and speaking about their work. He argues that this is necessary to support those "trained, fair-minded observers" that society needs: free stuff is so often worth every penny. Contrast this argument with the adviser who told a UK minister I was meeting last year – apparently in all seriousness – that all was well with the income of the creative classes by pointing to the average income (an average which, of course, includes J. K. Rowling and the Rolling Stones).

In *The Internet is Not the Answer*, CNN columnist Andrew Keen goes among the Silicon Valley hipsters – those who truly believe they are on the verge of joining the 1 per cent who own half the winner-takes-all economy – and he is not impressed. Keen is bombarded with sloganeering about "choice" and "media democracy", and observes instead "the resurrection of a pre-industrial cultural economy of patronage determined by the whims of a narrow cultural and economic elite rather than by the democracy of the marketplace".

His prescription for saving us from a monoculture is, basically, using anti-trust law to break up the monopolies. But such lawsuits take decades.

In *Rise of the Robots*, Ford coolly and clearly considers what work is under threat from automation. From reporting to composing film music to driving to doctoring: a whole new range of work will go the way of the assembly-line worker.

All three of these writers acknowledge their intellectual debt to *Who Owns the Future?*, a 2013 book by Jaron Lanier, the researcher who coined the term "virtual reality". Once again, Lanier has started a trend.

But more sequels are justified than these books alone. In particular, I would like to see one that can comprehensively examine Lanier's central prediction: that Google will eat itself.

Currently, Google stands as proxy for all the corporations that eke out a fortune by copying creative works and selling ads alongside them. But, as Lanier observes, if 3D printing becomes a practical alternative to mass production of physical goods, then everything will be distributed as a digital file. Google will encourage you to "share" – its favourite euphemism – the files that allow you to print the thingummy of your choice. What will then be left to advertise? And how will the industrial designers whose works are "shared" pay their rents?

"From composing film music to doctoring: a range of new work will go the way of the assembly worker"

Ford considers the spectre of economic collapse raised by the breaking of the bargain whereby workers who make stuff were paid enough so that they could buy stuff. His solution is startling: an unconditional basic income payment of $10,000 a year to everyone in the US.

Although he observes that this will be howled down as old-school "socialism", he points out that economist Friedrich Hayek, darling of the anti-socialist howlers, strongly supported the idea of a basic income payment. And from a different political perspective, noted British TV economics correspondent Paul Mason promoted it in *The Guardian* newspaper less than two weeks ago.

In 1964, *New Scientist* assembled a pair of books entitled *The World in 1984*, containing many essays from the great and good of those times. Several contributors mulled over the "problem of leisure": how would society cope with automation destroying most jobs? The matter is finally coming to a head for those who make a living by their brain as well as those who rely on their hands.

But what will the supposed leisure class read, watch and listen to? What will we know? And will we have food and shelter? ■

Mike Holderness chairs the European Federation of Journalists Authors' Rights Expert Group

Saving our songbirds

Activists are putting themselves on the line to fight illegal hunting, finds **Phil McKenna**

Emptying the Skies directed by Douglas Kass and Roger Kass, narrated by Jonathan Franzen. See bit.ly/EmptyingSkies for details

WHEN a group of vigilante birders trespass on a poacher's private garden and start destroying property, you know things aren't going to end well. Hitmen arrive and start hurling rocks. A birder flees, two others are kicked while lying on the ground, and a reporter falls face first into a fence. Such is the drama of *Emptying the Skies*, a disturbing documentary based on an essay by the writer Jonathan Franzen.

Half a billion songbirds are killed each year as they migrate between Europe and Africa. Historically, farmers across the Mediterranean captured and ate a small number of passerines during the autumn and spring migration. Now poaching occurs on an industrial scale. Non-traditional methods such as thin "mist" nets allow individuals to capture tens of thousands of birds in a single night.

Franzen first reported on this in an article for *The New Yorker*. In this film, he teams up with long-time director-producer team, brothers Douglas and Roger Kass, for a closer look at the activists who risk their lives to save birds.

Emptying the Skies takes us into a grey world of activism, where members of the Committee Against Bird Slaughter (CABS) often break the law in order to enforce routinely overlooked anti-hunting laws. "They may be a little crazy," says Franzen, who is the film's executive producer and narrator, "but the situation… is enough to drive you crazy."

With populations in precipitous decline, the killing of migratory songbirds was outlawed nearly 40 years ago under Europe's "Birds Directive". The practice remains widespread, however, as we see when the film takes us to a French restaurant. There, patrons with cloth napkins draped over their heads eat ortolan (*Emberiza hortulana*), a yellow-throated bunting that migrates between northern Europe and West Africa. The napkins are said to help capture the bird's aroma, yet also make the ghastly indulgence seem all the more macabre.

From the film, we also learn that between 10 and 15 per cent of bird species worldwide are now endangered, and that of these roughly half are migrants. Birds with a wide range are particularly susceptible to habitat degradation and climate change, so the additional killing of millions hastens their decline.

What struck me most about *Emptying the Skies* was how it humanised the activists who routinely risk their lives to save individual birds. Franzen rightly notes that rescuing 100, 1000, or even 50,000 birds has no effect on the extinction or preservation of a species. Yet by giving a voice to these otherwise voiceless creatures, CABS is making steady, albeit slow, progress ending the unsustainable slaughter.

When members of CABS began working in Brescia, northern Italy, in the late 1980s, they were greeted by mobs of angry hunters who shot at them, broke their car windows and, on occasion, their bones. Today, few poachers remain in the area: attitudes towards poaching have changed, and the Italian government now takes illegal bird-hunting more seriously and enforces the laws. Even so, there is still much work to do, and time is not on the side of CABS, a small organisation trying to take action across Europe.

"It occurs on an industrial scale: mist nets can capture tens of thousands of birds in a single night"

One of the battlegrounds is Albania, in south-eastern Europe, where I recently experienced emptying skies first hand. Historically, millions of ducks, geese and other migrating waterfowl funnelled through the Balkan peninsula in spring and autumn, stopping to refuel in the coastal wetlands. In the protected wetlands I visited, I often saw more shotgun shells and illegal hunting blinds than living birds.

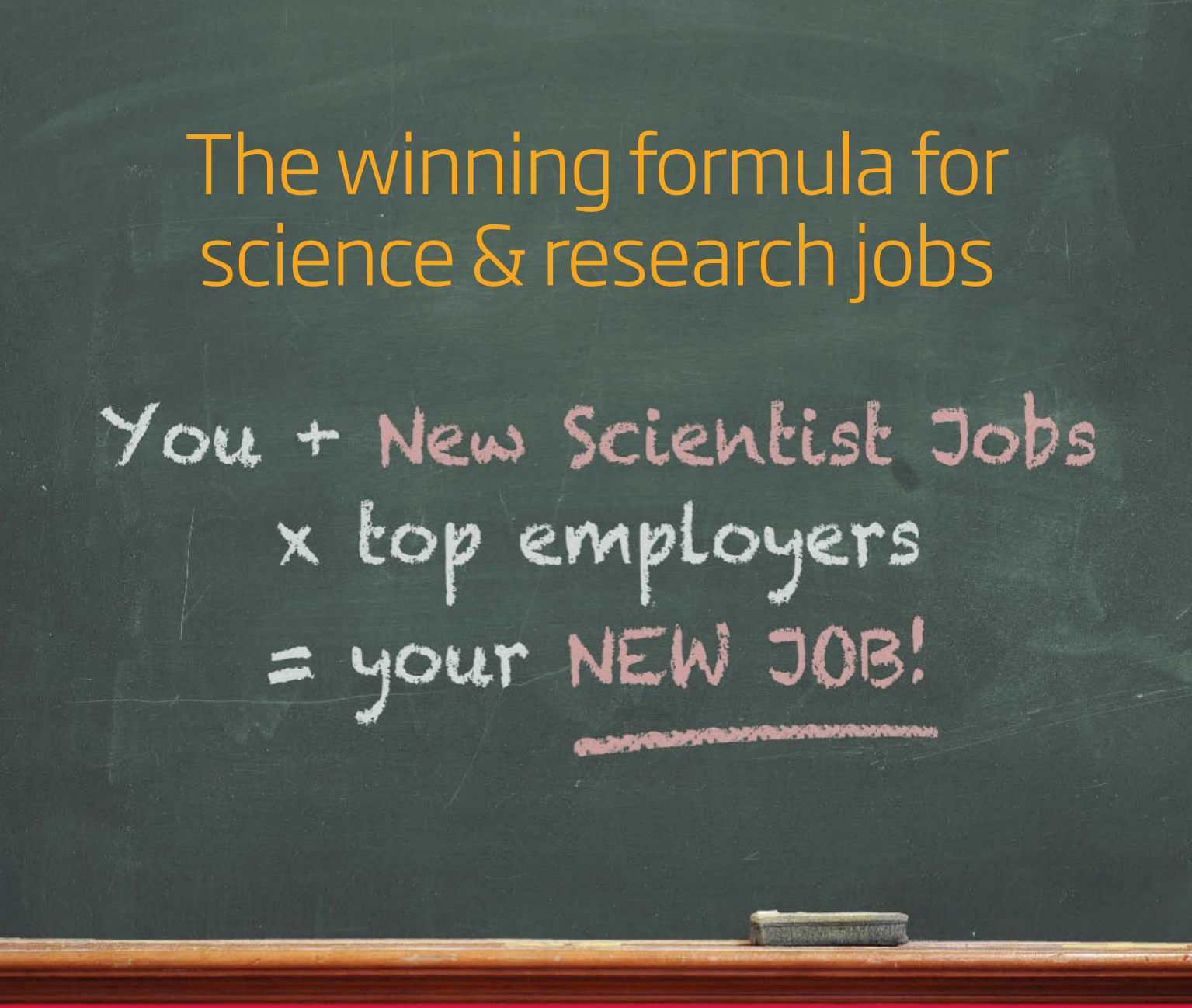
In October 2014, CABS member Tamás Kiss screened this film at a conference focused on combating illegal bird killing in Durrës, Albania. Since then, four Albanian conservation organisations have teamed up to enforce the country's hunting ban.

It seems the voice that CABS first gave to songbirds decades ago is finally being heard. ■

Bird man saves European robin – but species still face decimation

COURTESY OF LITTLE WING LLC

Phil McKenna is a science writer



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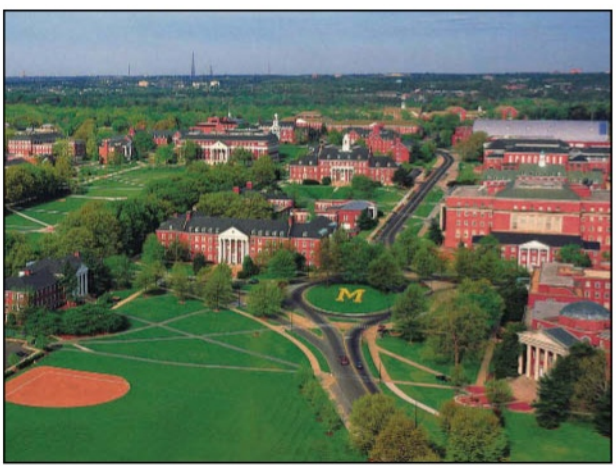

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Dr. Maryann Donovan, PhD, MPH
Associate Director for Research Administration, UPCI
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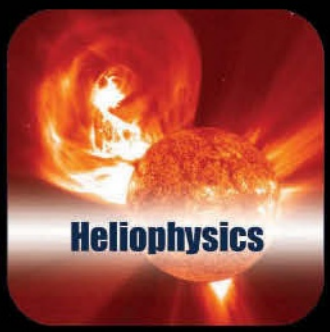

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POSTDOCTORAL POSITION focusing on synaptic dysfunction in autism spectrum disorders using cutting-edge electrophysiological measurements is available at Washington University School of Medicine, St. Louis, MO. Position is fully funded for at least 3 years with an option to extend for additional fully funded 1-2 years.

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Applicants with extensive experience in single-channel recordings are particularly encouraged to apply.

More information can be found on the lab website:
www.klyachkolab.wustl.edu

Qualified applicants are expected to hold a doctoral degree in neuroscience, biophysics, physics, or biomedical engineering, and have extensive experience in electrophysiology and familiarity with MATLAB programming. Trainee will work in a highly interactive multidisciplinary research environment at Washington University, which has been consistently ranked among the top five Medical Schools in the country. Highly competitive salary and benefits are available and will commensurate with experience.

Interested applicants should provide their CV and the names of two/ three references via email to:

Vitaly Klyachko, PhD
Assistant Professor
Department of Biomedical Engineering
Department of Cell Biology and Physiology
Washington University School of Medicine
E-mail: **klyachko@wustl.edu**
Website: **www.klyachkolab.wustl.edu**

Postdoctoral Positions

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Visit our website at **www.uab.edu/postdocs/openings**, to view positions. See info also on MERIT Program, an NIH IRACDA program. Send your CV to the contact name for the positions that you are interested. University of Alabama at Birmingham, Office of Postdoctoral Education, 205-975-7020.

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Fall Preview will be held October 15 - 16, 2015
Application will open in July

The true cost of meat

From Gregory Sams
As the creator of the original veggie burger in 1982, I read Linda Geddes's story on the cost of meat consumption with interest (24 January, p 30), but I could not ignore the inherent bias towards animal protein being superior.

Much is made in the article of meat being a "one-stop shop" for the essential amino acids, as if eating rice and beans is a big hassle for those billions across the world whose diets are based on pulses and cereals.

In combination, these foods provide all the essential amino acids plus slow-burning carbohydrate energy. People supplement them with vegetables, oil seeds, fruits and, sometimes, animal products.

For millennia we have raised animals on non-arable land and fed them indigestible waste from our food production, either harvesting their milk or their meat in return. Eating meat was occasional.

Government intervention in the food chain aimed to put meat on our plates every day through subsidy and regulation. The result of this policy was factory farms, agribusiness, a reduction in quality and consequences for human health.

Were government to exit the food chain, meat would be left to the mechanics of the marketplace and prices would rise to a level that would temper the amount consumed. We do not need to tax meat, just to stop subsidising it.
London, UK

From Dan Conine
Geddes's article echoes previous ones in suggesting that we must reduce our consumption of meat through a combination of education and policy change.

The consensus seems to be that scientists can only see the human animal as a mindless consumer of resources. This fits the common urban model of civilisation that increasingly isolates humans from the world we evolved in.

I submit that everyone needs to stop and think that perhaps the problem is not meat or money, but that humans are living as though everything on the planet is supposed to serve us, rather than the other way around.

The opposite of consuming Earth through unfettered rapacity is not frugal rapacity; it is unfettered generosity to Earth.
Belgium, Wisconsin, US

Banking on friends

From Carl Zetie
Reading Chris Baraniuk's article on group investing in the housing market, I was reminded that this is not the first time individuals

have banded together to finance houses, bypassing the banks (24 January, p 21).

The British building society movement, which began in Birmingham in the late 18th century, enabled newly prosperous citizens to pool their resources to build their own homes.

These building societies remained a distinctive element of the British housing ownership landscape until the 1980s, when many of them demutualised, in the process becoming indistinguishable from banks.

The original building societies were inherently local, forming among people who knew one another well, meeting in bars and coffee houses rather than websites and forums. So perhaps we should think of crowdfunded mortgages as the reinvention of the building society for the digital age.
Waterford, Virginia, US

Universal principles

From Ed Prior
I have great respect for Lee Smolin's work in cosmology and physics, but I cannot accept his "first principle" that there is just one universe (17 January, p 24).

In ancient times, our ancestors believed there was only one sun – our own – and worshipped it as a deity, not realising that stars were really suns like our own.

At the beginning of the last century, astronomers believed that there was only one galaxy in the universe, our own Milky Way, until Edwin Hubble's measurements showed otherwise.

More recently, virtually all astronomers believed that the universe was still expanding after the big bang, although this expansion was gradually decelerating due to the pull of gravity.

Adam Riess, Saul Perlmutter and Brian Schmidt and their teams found that the expansion rate was increasing – a result that remains unexplained.

Smolin and his colleague Roberto Mangabeira Unger may be right that there is only one universe, but that is a conclusion that can only be reached after further research, not by an assumption.
Poquoson, Virginia, US

Sellafield danger

From Douglas Cross
Fred Pearce highlights only a few of the problems posed by the UK's Sellafield nuclear reprocessing plant (24 January, p 8).

While he mentions the new generating station being built at Hinckley Point in Somerset, he appears not to have noticed that there is to be another less well-publicised project, literally on the other side of the fence at Sellafield.

The decision to build the new Moorside station immediately next to what Pearce rightly refers to as one of "the world's most dangerous radioactive waste stores" indicates how far from rationality the government's energy planning has wandered.

While new-generation nuclear power plants may indeed be far safer than those now being decommissioned, any major discharge from Sellafield next door would require an immediate and possibly permanent shutdown of this idiotic £10 billion project.

If this is an indication of the shape of things to come, then those responsible for this parody of risk awareness need to be moved somewhere where they can do no harm.
Lowick Bridge, Cumbria, UK

Soleful exercise

From Martin Murray
I read with interest Laura Spinney's article on the effect of shoes on our feet (24 January, p 40). I immediately thought how much an hour of t'ai chi each week could do to undo the damage done by shoes.

T'ai chi is done in soft slippers and uses "soft feet" – the step lands on the heel and rolls softly on to the ball of the foot. The exercise is sufficiently slow that

the energy stored in sinews does not come into play; instead the muscles and joints of the foot and ankle are developed.

This results in a foot that is flexible but strong, and probably as close as we can get to its natural condition. Researchers could learn from this exercise form.
Telford, Shropshire, UK

From Roger Malton
An interesting extension of the ideas in Spinney's article on feet might be to research people who take part in dance activities.

I'm involved in traditional dance, mainly Scottish country and highland dancing, which are high impact and involve dancing almost exclusively on the toes.

Both make use of constricting footwear with thin soles and very little ankle support. I frequently hear of people getting foot and ankle injuries – the accelerations and changes in direction are very similar to those in football and many other sports.
Newcastle upon Tyne, UK

Raising the bar

From Bruce Skinner
Dan Jones reports a study showing that lawyers with more masculine voices are less likely to win a US Supreme Court case (3 January, p 12). He suggests that courts might have a bias against such voices, and that if so, this bias needs correcting.

This ignores a basic tenet of statistics – correlation does not imply causation. This may be the other side of the "glass ceiling" which prevents some women from being promoted despite having the ability: it may also favour less competent men with an authoritative presence.

Rather than showing a bias in the trial system, the objectivity of trials may be casting a light on flawed selection of lawyers.

Perhaps job interviews for lawyers should be conducted in writing, without any face-to-face meetings, by impartial judges who don't know any of the applicants.

Politicians and CEOs with deep voices may be more successful in terms of winning votes, or earning money, but if there was an objective way to measure their competence, I wonder if their track record would be any better than the lawyers studied.
Macclesfield, South Australia

Roman wives

From Duncan Cameron
Roman soldiers defied the rules to house their wives in forts, writes Jeff Hecht (17 January, p 13).

In addition to the evidence he supplies, I would draw attention to the texts on the Vindolanda tablets, the oldest surviving handwritten documents in Britain. These show that some women at least made their homes within the fort complex.

These postcard-like wooden tablets were the internet of their time, used to correspond with Roman sites around the country.

Notable is a message from Claudia Severa to her friend Sulpicia Lepidina, offering an invitation to a birthday party. This letter is written in perfect Latin in two different handwriting styles, indicating that some of it might have been dictated to a professional scribe.

The letter was found in a hoard of tablets alongside more regular administrative correspondence, which suggests that it was delivered via a Roman military courier system. This would be natural if the recipient Lepidina had a recognised status within Vindolanda fort.

The text tells us that some form of family life was established in Roman forts. If older generations of scholars have difficulty with this concept, as archaeologist Carol van Driel-Murray reports, I suggest they go back to the drawing board.
Brighton, UK

Roller coaster ride

From Peter Borrows
Stuart Farrimond examines the radical treatments that could stop his brain cancer (10 January, p 10).

John Wardley, the man who designed many of the roller coasters in UK amusement parks, recounts in his autobiography the story of a girl who had a brain tumour the size of a satsuma. It was stopping fluid moving around her brain and would have killed her.

Suddenly and unexpectedly the fluid in her brain dispersed,

relieving the pressure and allowing surgeons time to operate. The only explanation offered was that a few days earlier she had been on the Colossus roller coaster at Thorpe Park.

Did medical researchers ever follow this up? If I develop a brain tumour, could subjecting myself to significant *g*-forces on a theme park ride offer me hope?
Amersham, Buckinghamshire, UK

In bad faith

From James Whalley
Sociobiologist E. O. Wilson says religious faith is "dragging us down" (24 January, p 28). What a tremendous clarion call!

But if it is true, as he says, that humans have a strong tendency to wonder about whether they are being looked over by a god, and that practically every person ponders whether they are going to have another life, then there's precious little hope that we'll escape being dragged down.

These questions can be asked only by those who have not taken on board what biology and cosmology have taught us over the past two centuries, because they reveal an anthropocentric attitude – which is exactly what is allowing us to destroy biodiversity, and ultimately ourselves.
Howick, Quebec, Canada

Plane thinking

From Tom Roberts
Hal Hodson writes about plans to launch networks of satellites that provide global internet access from orbit (31 January, p 18).

But why not use the thousands of aircraft flying around the world instead of turning to communications satellites? At any one time there are about 5000 planes over the US and 13,000 in the air worldwide. All of these could be tracked (if we wanted) and employed to relay laser communications.
Derby, UK

For the record

- **We wrote that plastic fibres were up to four times more abundant in deep-sea sediment than surface water (31 January, p 28). The true figure is four orders of magnitude greater (10,000 times more abundant).**
- **Very thaw point: the lower blue line in our sea ice graphic (31 January, p 42) was the Antarctic summer minimum, not the winter one.**

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PAUL MCDEVITT

PUBLICIST Diana Ziskin writes to alert us that "The creators of MyPeriod Tracker App are five typical guys who were tired of the drama, discourse and sometimes absurd fights they would come home to with their wives and girlfriends when they had no idea it was 'that time of the month'."

An attached advert for the phone app, in which women can share their cycle with their partners so that "your relationship can once again run more smoothly… yes, even during that week!", has the guys saying that it "was borne [*sic*] out of our need for survival and to better understand and be able to support our wives". Some readers may visualise a pause after "survival", followed by the blenching of a man who realises he had better backtrack, entirely unconvincing though this effort is.

Given the date of this issue of *New Scientist*, a curious Feedback wonders how well one of these would go down as a Valentine's Day gift.

LONDON'S Natural History Museum attracted a great deal of publicity in January for its announcement that it will replace the iconic copy of a *Diplodocus* skeleton in its entrance hall with a real blue whale skeleton. As Susan Parker observed on the day of the announcement, "Dinosaur fans everywhere will be weeping into their cornflakes." And they did, indeed lobbying to #savedippy.

But "the important thing", as Susan puts it, "is that this will give a proper perspective on the standardised blue-whale unit of measurement – whereas we don't tend to talk about multiples or fractions of a *Diplodocus*." Not yet, we don't. Feedback's mailbag quivers in expectation.

PERHAPS the above-mentioned cetacean should instead be moved to the International Bureau of Weights and Measures in France to serve as the Standard Blue Whale?

On a related topic, Feedback was discussing with friends the problem of using the football pitch as a unit of area owing to the variation between pitches (25 October 2014). As a sportophobe, we found ourselves in the unusual position of agreeing with Manchester City fans in proposing that the Manchester United pitch be made the standard, moved to Paris and kept under glass in a vacuum.

CONFUSINGLY, Jack Harrison reports a way to combine whales and football into a measure of time. He spotted a poster in Tobermory on the Isle of Mull that announces: "Sperm whale – can dive to over 1000 metres and stay underwater for the duration of a football match".

COINCIDENTALLY, we think, several readers wrote at the end of January to ask: "whatever happened to the double-decker bus?" This, as Richard King observes, "was the standard unit of weight when I was young". The "Routemaster" bus, now banished to London heritage status, has a mass of 7.47 tonnes – or, in the new non-metrocentric international units, 1.5 African elephants.

Rob Macfie thus questions the use of the outdated unit by Sheffield City Councillor Jayne Dunn, who proudly announced that about 188 double-decker buses of salt had been spread to de-ice that city's roads.

Alex MacDonald and Richard Bamborough both noted that new nuclear waste vaults at Dounreay in Scotland were reported in the *Daily Record* as being "equivalent in volume to between 370 and 450 double-decker buses". Feedback wonders whose interests are served by using a superseded unit of volume.

MORE disturbingly, Alex MacDonald also forwarded a report from the *Aberdeen Press and Journal*, also in Scotland, that a soundproof building at the Lossiemouth Air Force base "would be able to silence the fighters' twin engines – which are the same as 32 double-decker buses". Feedback has enough trouble comparing decibel values given plainly: this really makes our head hurt.

SPEAKING of buses, Sofia Graves writes: "When you travel on the bus from Majorca airport into the city, the first stop is announced as 'Joan Maragall Street – Virtual'." She hasn't "had the guts to explore what would happen if I got off at a virtual stop".

If she got off, would she be able to bypass the 8-kilometre journey to Joan Maragall Street – Real?

FINALLY, we were a little piqued by the feature on writing poetry in computer code (27 December 2014, p 51). Feedback was rhyming in the Pascal language a quarter century ago.

Anne Sproule does much better by sending poems apparently produced by computer code. The

title of each poem is a word that you enter into a search engine: the body is the suggestions it provides you, at that moment, on what you might be looking for. Anne gives two examples:

THIS: This is the end / This American Life / This is why I am broke / This is 40 / This means war!

WHY: Why is the sky blue? / Why am I so tired? / Why do we dream? / Why do dogs eat grass? / Why am I always so tired?

Hunting through his cupboard, Ian Wells found "Carex fun edition handwash". He wonders what the boredom or terror editions do. We're boggled by "Cola Bottles" and "Strawberry Laces" scents

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Algal bloom

If Earth were to be suddenly devoid of all life, but otherwise unchanged, and I were to drop a single photosynthetic bacterium or alga in the ocean, how long would it take to colonise all the seas? And how long to colonise the land?

First, let's make some assumptions for a simple model, some of which ease the computational task. We'll work with powers of 2, which means we only multiply or divide by 2. Thus we'll round up Earth's surface area from about 510 million square kilometres to 512 million. Until a biologist provides a different figure, let our alga be 1 square micrometre in size. Finally, a common school question has lily pads doubling in area every 24 hours, so we'll use this as well.

"If algae doubles in size every day, in 90 days it would easily cover the surface of Earth"

So, how many days does it take to go from 1 square micrometre to 512 million square kilometres, if our algae doubles in area every day? In 90 days it would easily cover the surface area of our model Earth. That would include the surface area in many caves and all other land features.

Using a rough figure of 75 per cent for the area of Earth covered by sea, our alga would still need the same number of days to colonise the oceans as the entire planet, as day 89 represents 50 per cent planet cover.

However, like any model, this needs to be taken with a pinch of salt. A few things that could easily happen to render the model invalid include the possibilities that the alga may only grow in salt water, so cannot cover land or fresh water; that death from starvation may slow growth; or that other outside factors such as inappropriate climate in some locations may also slow growth.

Finally, if 1 square micrometre seems big for an alga, changing its size to 1 square nanometre adds just 10 days to the model.

David Morton
Geeveston, Tasmania, Australia

Algae, which is Latin for "seaweed", is a diverse group of species, ranging from single-celled organisms to the 50-metre-long giant kelp *Macrocystis pyrifera*. Like plants, algae are autotrophs and make their own food, harnessing sunlight to synthesise sugars from carbon dioxide, and producing oxygen as a waste product.

Imagine starting with an individual *Pediastrum boryanum*, which is about 10 micrometres across. If it only reproduced asexually (by dividing in two) it would take 85 generations to cover all the oceans. If each generation reached sexual maturity in 24 hours, this process would take about three months.

Algae are naturally aquatic, so the colony would need to wait for the development of another species with which it could develop a symbiotic relationship before populating the land, as has fungi with lichen.

In reality, individual blooms appear to form quickly because algae are fairly ubiquitous but don't become noticeable until the

"Algal blooms are not noticeable until the population density makes the water translucent"

population density is sufficient to make the water semi-transparent, with the population increasing 1000-fold in just 10 days. Of course the population density that defines a bloom depends on the species of algae, which also lead to different colour blooms. Some blooms, like the so-called red tide, are toxic and a threat to the local ecosystem.

Even in the absence of microscopic herbivores nibbling at its progress, the geographical reach of blooming algae would be curtailed because its requirements for sunlight, warmth and nutrients aren't present everywhere at any given time.

Indeed, algal blooms are often associated with pollution events, especially where nitrogen and phosphorus from fertiliser runs off into the ocean. A lack of nutrients at latitudes between 30 degrees north and south of the equator is why tropical waters are often referred to as oceanic "deserts". This results in the unusually clear blue water that attracts scuba divers.

Mike Follows
Sutton Coldfield, West Midlands, UK

This week's questions

SUPPLY CHAINS

It is fairly common for numbness to develop in an arm in which the blood supply has been temporarily shut off by lying in an awkward position. We normally notice when a limb goes numb and move, but could this also happen to an internal organ, and what would we feel if so?

Rachel Cave
Galway, Ireland

WHO'S ON TOP?

I found this spectacle (see photo, left) on Wimbledon Common. Is it an example of sexual dimorphism or are the participants fruitlessly confused?

Alex Tierney
London, UK

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